OUR SURROUNDINGS

AN

ELEMENTARY GENERAL SCIENCE

CLEMENT - COLLISTER

THURSTON

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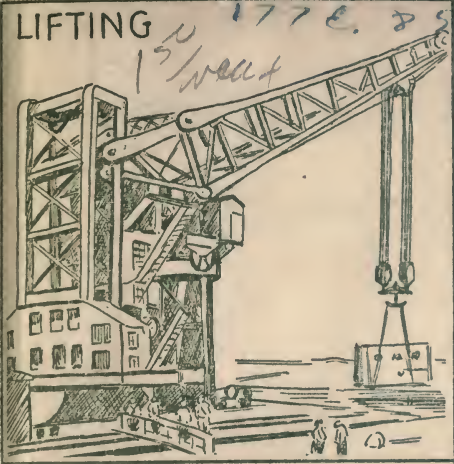

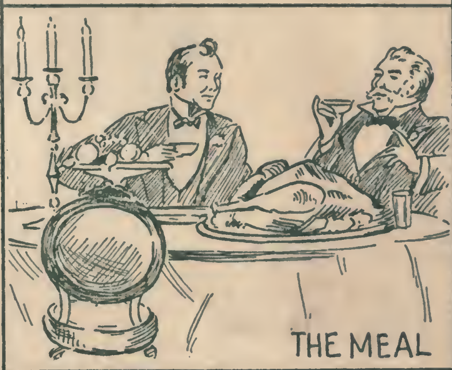

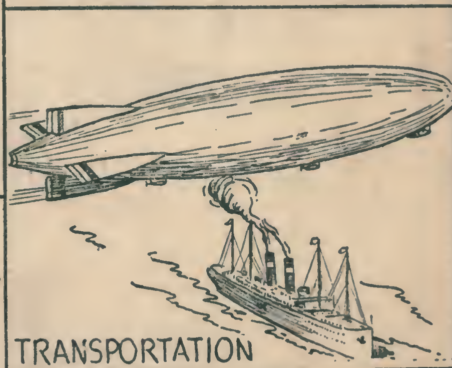

SCIENCE TODAY

Pure Science

OUR SURROUNDINGS

An Elementary General Science

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Gen Science

THE IROQUOIS PUBLISHING COMPANY, INC.
SYRACUSE, NEW YORK

6.35 C

Printed in United States of America

PREFACE

The immediate aim of OUR SURROUNDINGS is to place the pupil in tune with the common things about him, giving him an understanding and appreciation of, and an interest in, his environment.

OUR SURROUNDINGS draws upon many sciences to bring about this contact and understanding. With the help of these sciences it opens the door through which the pupil sees the true importance of the familiar and common things about him. It does more. It fires the pupil's interest, awakening the desire to go farther afield and to explore in more detail the territory of some particular science. It gives the preliminary view and contact that make possible an intelligent choice of the sciences for more extensive and intensive study in later school years.

In this connection the Fifth Year Book of the Department of Superintendence of the National Education Association says: "It is difficult to understand how many pupils in the junior high school can be guided intelligently in their choice of differentiated curriculums unless the field of science is revealed to them and their aptitudes are determined for the science electives."

General Science, as a subject, has developed during the last twenty years. It has largely been introduced into the ninth year. Undoubtedly it is destined to become a major course for the three years of the junior high school. Of such a course the Fifth Year Book says: ". . . the dominating idea for the seventh year may well be the study of plant and animal life, going somewhat beyond mere observational nature study, as is appropriate in view of the increased maturity of the pupils. For the eighth year the determining theme might well be health, comprising in the subject-matter of instruction the manifold topics relating directly or indirectly to the maintenance and upbuilding of individual and community health. For the ninth year, the dominating theme might be man's control of his environment, including in the subject-matter of instruction studies of the sources of material and energy, and the transformations and uses of both."

Our Surroundings, while covering in detail the field of the ninth year course, has provided as well the background of the earlier years as outlined above.

It is commonly accepted that the content of the regular course in general science, as given in the one-year form, shall be selected largely from the environment of the pupil. True, environment varies markedly in different localities, but there is much in science common to the lives of all. Air, water, soil and food are essential to all environments; so are light, sound, heat and motion; so are health and the weather. The strength of a textbook in general science lies in part in the wise selection of material from the wealth of subject-matter. In the construction of Our Surroundings exceptional consideration has been given to the content, especially with reference to the essential factors common to all environments, and to those wider applications of science which affect the pupil indirectly and which can be understood through the knowledge gained in a study of his immediate surroundings. This has resulted in a book that meets the requirements of any standard syllabus.

The story of Our Surroundings is told in three ways. The *introductory sections* of each chapter capture the pupil's attention and fix his interest on what follows. A unifying thread runs through the entire series of introductions so that if read consecutively as an independent group they sketch vividly the field of general science and bring out its basic facts.

The story of general science is told again in the *main text,* in simple, direct language, with scientific facts and laws presented in logical order and properly related. It forms a readable, well-organized treatment of the subject, complete in itself, and not dependent on supplemental aids for an understanding of its meaning.

The story is retold in vivid *illustrations and diagrams,* with crisp, pointed, thought-provoking captions, to arouse interest and the spirit of investigation.

General Science, as developed in Our Surroundings, is not a patchwork, made up of unrelated parts of special sciences, but is a unified whole. In the treatment of topics, the relation of

one to another is made clear by constant reference to the great truth, or unifying principle, which binds together the separate sciences in their relation to general science. This is the principle of the conservation of energy, which teaches that energy can neither be created nor destroyed, although it can be transformed to other forms without loss.

Says the Fifth Year Book, again: "Our knowledge of science to be of the largest service must be in the form of principles and laws. Application of our knowledge of science to problem situations is a deductive process. Faced by a difficulty, we cast about for the law or principle that applies to it, and thus reach a solution. It would seem that the design of the course of study in science for the junior high school should enable the pupils to have experiences with an attainment of knowledge of those laws and principles that are socially worth while, and should provide much drill in applying them to life situations."

This reflects the thought of the authors of OUR SURROUNDINGS. The book emphasizes basic principles and laws. These are made clear as the need for their use arises. Experiments are introduced at the start, and the scientific method in experimenting is at once made clear. Experiments and demonstrations are interwoven with the general text in such a way as not to break the continuity, but to emphasize the truths taught.

Supplemental work, in the way of individual and group projects, is provided with each chapter. These not only outline definite work, but are suggestive of other exercises in the same lines. In addition, a feature is made of topics for outdoor observation. These serve to focus the attention of the pupil on his surroundings.

A special feature of the book are the carefully built fact and thought questions which arouse interest and stimulate the pupil to further questioning of his surroundings and to finding new applications of the laws and principles he has been studying. Something new is provided in the groups of questions for discussion and review which are placed at intervals throughout the book. These offer a continuing review, helping to keep well in mind facts and principles already taught.

Technical terms are made clear to the pupil as they are introduced. They are explained naturally and simply in the text. In addition, clear, direct definitions of important terms are given in an unusually complete glossary. The possibilities of this glossary are not limited to reference use. It is so extensive that it offers unusual opportunities for review and drill.

General Science offers exceptional possibilities in the way of arousing interest, of awakening intelligent questioning, of testing aptitudes, and of placing a pupil in right relations to the surroundings in which he lives. It has a further appeal to the pupil who still dwells in the hero-worship period. The Fifth Year Book says: "The discoveries of great scientists, illustrations of their method of work, their devotion to the search for truth, their sacrifices and triumphs—all these bring vividly to the pupil appreciation of what the development of science has cost, and an understanding of the scientific attitude of mind with a desire to make it his own." There is something in general science for everyone no matter what his likings or abilities.

Science books must be constantly undergoing change, as the student may learn by following the scientific writings from year to year. Scientists are constantly making new advances which affect the comfort of peoples everywhere. The last chapter of this book records some of the latest discoveries. The pupil should find unusual interest in this final chapter.

Our Surroundings seeks to draw from the wealth of scientific material that which is most worth while for all; and to present it in various ways with a simplicity and clarity of language and illustration that will enable each student to make it his own, thereby helping him to find in it many points of real inspiration. It aims to make each student healthier, happier, more interested in the things about him and better fitted to adjust himself to the world in which he lives.

The Authors.

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EXPERIMENTS AND EXERCISES

A proper understanding of the experimental method is absolutely essential for successful work in General Science. Too often students fail to grasp the value of this work. It is, therefore, all important that the right foundation be laid at the beginning to understand and appreciate the value of the experiment in the study of science.

Experience has shown that much time is wasted owing to the student's failure to properly perform the experiment and apply it. The fact that constructive help will add largely to the interest and understanding of the student is a sufficient reason for giving much assistance which in more advanced science courses would be unnecessary and unwise.

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TO THE

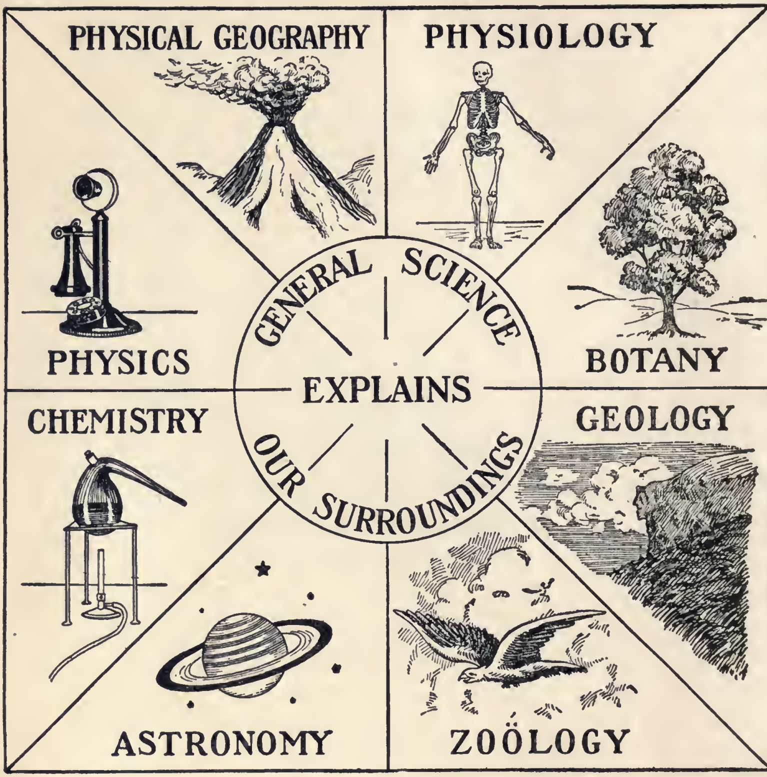
BOYS AND GIRLS

WHO WILL BE THE SCIENTISTS

OF TOMORROW, THIS BOOK

IS DEDICATED

OUR SURROUNDINGS



General Science opens the door through which we see with new eyes the things which surround us, enabling us to understand them in a wider and bigger way. Many different sciences help to give us this knowledge. Later on you will enjoy studying some of these special sciences more in detail.

CHAPTER I

THE MEANING OF SCIENCE

Most of us have read the story of Aladdin, the boy who had the magic lamp. When he was hungry, he had merely to rub the lamp and a genie appeared, who brought him whatever food he wished. If he wanted a new castle, he rubbed the lamp and—lo!—the genie brought the castle and set it down wherever the boy desired.

A wonderful story? Yes, but more wonderful things have really happened. Man was once helpless and alone in a savage world. Powerful beasts hunted him and he fled to the trees in terror. At night he shivered from the cold. The oceans, lakes and rivers checked his travels, for he had no means to cross them. What he could not do by his own strength remained undone. Then man found his genie, a giant by the name of Science.

Today, aided by this giant slave, man can do feats more wonderful than those of Aladdin and his genie. He can turn on his radio and draw out of the air the music of a band playing thousands of miles away. He can step into an airplane and travel farther in an hour than he once could in a week. He can pull a lever on a derrick and hoist a weight of fifty tons. He can travel through the sky, or far beneath the waves. All this he owes to his great slave—Science. Who is this giant, Science?

There are few wants today that Science cannot satisfy. We enjoy remarkable pleasures and comforts. We move at will on land and sea, and in the air. We use enormous power with hardly a thought. Yet to live understandingly, we need to know something of the materials and of the forces at work in the world. A study of General Science opens the door through which we see the importance of the familiar and common things about us.

Suppose we were taken unexpectedly from the civilized world in which we live and were set down in a wilderness without any of the man-made objects which are now so much a part of our daily lives. Imagine how uncomfortable and helpless we would

feel. We would have no comfortable houses, with all their modern conveniences. We would have no easily-made fires, for we would be without matches. There would be no great markets with food for our use brought from all parts of the world. We would have no means of travel of any kind save our own feet. We would be without books and papers. We would have no ways of heating in time of cold; no light to dispel darkness; no clothing,

United States National Museum.

Life When Science Was Just Beginning

as we know it; no medicine for use in sickness. We would be without tools with which to build, and without proper weapons with which to hunt or to protect ourselves. Our lives would be a desperate struggle to obtain food, to safeguard ourselves against dangers and to find shelter from storm and cold.

Suppose, in addition, we knew nothing about the laws of health, nothing about how to grow plants for food, and had little under-

standing of the common things about us. Thunder and lightning and unusual signs in the skies would frighten us. Nature itself would seem to be hostile, fighting against us. Yet this was the life of early man.

Progress from that age to the present has been made slowly, step by step. Probably there would have been little progress at all in the world if each generation had had to discover over again

Brown Brothers.

LIFE IN THE SCIENTIFIC AGE

the things which the previous generation had learned by experience. Fortunately, early discoveries could be passed on to those who came after, and so each new generation added something to the gathering store of knowledge.

At first knowledge was passed on uncertainly and often inaccurately by word of mouth. Only when writing was invented did general knowledge begin to grow and spread. It spread far

more rapidly with the invention of printing. Today, we of the present profit by the discoveries of the past. We use this knowledge, build upon it and add to it by means of new discoveries. All these facts that man has learned about Nature when sorted and grouped are called Science. *Science is the classified knowledge of the facts concerning Nature.*

Man has always been most interested in his environment, that is, in the every-day things which surround him. Science helps us to understand this environment and, as a result, to live in it much more comfortably. Because of Science, Nature is no longer looked upon as the enemy of man, but as his friend and helper.

The scientific knowledge of the world and its relation to man is so vast today, and so many are the fields in which further study can be carried on, that no one person can hope to master more than a small portion of it. For convenience of study and investigation, therefore, Science has been divided into a number of branches. There is *Chemistry,* which tells us of the materials of which things are made, and of what happens when substances are combined or broken up to form entirely different substances. There is *Physics,* which tells us of certain forms of energy, such as motion, heat, light, sound and electricity, and of how they work. There is *Astronomy,* which tells us of the stars and planets, and of the relation of our earth to them. There is *Zoölogy,* the study of animals; *Botany,* the study of plants; and *Physiology,* the study of our bodies. There is *Physical Geography,* which tells us of the earth's surface and its changes, and *Geology,* which tells us of its structure and history. *General Science* takes from each special branch of Science what we need to know in order to understand and to use for our good the common things of our surroundings.

Scientific Method.—Few important scientific truths have been stumbled upon by accident. As a rule, scientists work by a definite plan called the *scientific method.* When they want, for example, an explanation of something they have seen, they first make many observations and experiments. They study the results of these observations and experiments very carefully, trying to

explain them so far as possible by facts already known. This explanation they call a *hypothesis,* that is, something that they think is right but have not proved. Then they try out this hypothesis in every way possible. If the explanation still seems to be true it is then called a *theory.* After many tests and trials of the theory thus formed, and probably after new and different experiments have furnished further proof that the theory is right, it becomes known as a *law* or *principle.*

Popular Science Monthly.

EXPERIMENTS LED TO THE COTTON GIN

As a result of a series of experiments, Eli Whitney constructed, in 1793, a machine that separated cotton fiber from cotton seed.

Isaac Newton discovered the law of gravitation. It is said that Newton's interest was aroused by seeing an apple fall from a tree to the ground. He knew that the apple had no power of motion and, therefore, that some outside force must have caused it to fall. He studied many other falling objects and from what he saw he made the hypothesis that all bodies are attracted to the earth in one and the same way. He also studied the motion of the planets around the sun and the motion of the moon around the earth. At last he announced the theory that all bodies are attracted toward

one another and that it is this attracting force that drew the apple to the earth and that holds the great planets in their courses around the sun. More experiments and a further study of observed facts have since made this theory a generally accepted law, known as the *law of gravitation.*

Importance of the Experiment.—An experiment is an attempt to find out by observation something that we do not know. For example, a physician feeds different kinds of food to rats in order to learn which of these foods are most nourishing. A farmer, who has lost his wheat crop on several occasions because of frosts, experiments with different kinds of wheat and tries to develop a new variety that will better endure the cold. The experiments with the rats and with the wheat are efforts to discover something unknown that, if known, would help man to make more of his surroundings. In the same way, most great truths have been discovered by long-continued and repeated experiments. Experiments are the very basis of the scientific method.

E. S. Houck.

COMPARING THE WEIGHTS OF WATER AND MILK

Here is a very simple example of the experimental method. Alice sees cans of milk being weighed at a milk station, and wonders whether these cans would weigh more or less if they were filled with water. Her curiosity is aroused and she decides to find the answer for herself. She uses the kitchen scales and two quart bottles. She weighs the bottles when empty, then fills one with milk and the other with water and weighs them again. She compares the records of the weighings and so reaches the

conclusion that milk is heavier than water. She has *observed* how much each liquid weighs, has *compared* one weight with the other, and has *concluded* which liquid is heavier.

The steps involved in an experiment are: (a) stating the problem; (b) securing the materials necessary; (c) use of the materials to produce a natural result; (d) observation and comparison of results; (e) conclusion drawn; (f) when possible, the practical application of the conclusion to the solution of new problems. Of these, *observation, comparison* and *conclusion* are the essential parts. Observation means taking careful notice of facts or conditions. Comparison means a study of the facts observed to discover how they compare with each other and with other known facts. Conclusion is what is believed as a result of this observation and comparison.

A knowledge of how to experiment will help us in our study of General Science. Many things about us are so familiar we do not appreciate their great importance until we experiment with them and begin to understand the scientific laws back of them.

Labels.—Whenever possible, it is helpful to make a simple drawing or sketch to accompany and explain experiments and demonstrations. Such a drawing should have a clear, definite title which explains just what it represents. Usually it is advisable to label all important parts. That is, the name of the part should be lettered on the drawing, or else the lettering should be placed in the margin and a line drawn to connect it with the part to which it refers.

All samples of material should also be labeled. That is, the material itself or its container should have attached a simple paper label stating exactly what the material is. Labeling of this character is helpful in using or classifying samples later, and is of importance in avoiding mistakes.

SUMMARY

Until Science made it possible for man to use the materials and forces about him, life was a bitter struggle for existence.

A knowledge of the facts and laws of Science helps us to improve life conditions. The extent of the field that Science covers

has made necessary its division into branches. Among these are Physics, Chemistry, Astronomy, Zoölogy, Botany, Physiology, Physical Geography and Geology.

General Science deals with the facts and laws of the common things of our surroundings.

The basis of the scientific method is the experiment, an act performed to discover or test some scientific truth.

The scientific method is the process by which most new discoveries of facts are made and by which new problems are solved. It includes experimentation and observation, and the formation of hypotheses, theories and laws.

A hypothesis is an explanation which is believed correct but which has not been proved.

A theory is a hypothesis the truth of which has been strengthened by experiments.

A law, or principle, is a theory which has been proved to be correct.

Fact and Thought Questions

1. Compare food-getting now and in the early ages of man.
2. What is Science?
3. Name and define several branches of Science.
4. What is included in General Science?
5. What is an experiment?
6. Complete this sentence: The main parts of an experiment are ——.
7. Observe a pane of glass in the schoolroom window, using the senses of sight and touch. Tell the results of your observations.
8. Suggest comparisons you might make as a result of observations of a horse and a cow.
9. Name several common occurrences in your every-day experiences for which you know the explanations.
10. Name several common facts in your every-day experiences you would like to have explained.

Projects

1. List under proper titles 50 common things in your home surroundings. Use such titles as inventions, animals, plants.
2. Prepare a list of five books in the school library that tell of common things.
3. Collect from newspapers or periodicals at least six short articles on common things.

Outdoor Observation

List under a descriptive heading all the uses of science you recognize on the way to school.

References

How We Think .... *Dewey*
The Secret of Every-day Things .... *Fabre*

CHAPTER II

MATTER AND ENERGY—THE FOUNDATION OF ALL SCIENCE

Nature is the greatest of magicians. She takes matter, which means any material, and energy, which is responsible for any force, and makes them seem to disappear. Vapor is matter; sound is energy. But what becomes of the vapor and the sound from the whistle of an engine?

For centuries men really believed that matter and energy ceased to exist when Nature made them disappear. At last, however, they discovered what actually happens. Instead of ceasing to exist, both matter and energy are merely changed into other forms. Nature cannot destroy either matter or energy.

Remember there are two things that can never be destroyed. One is *matter,* of which everything, whether lifeless or alive, is made. The other is *energy,* which causes all changes in matter, such as changes in position, shape, quality, or temperature. Together, matter and energy make up our earth, keep it in its path in the heavens, and make possible all growth and life upon it.

So we begin our study of General Science with matter and energy, because in these lies the foundation of *all* our special sciences.

Everything is made of material of one sort or another. A chair may be made of wood, a stove of iron, a bottle of glass, or a mountain of rock. The bottle that appears to be empty is full of air. Wood, iron, glass, air, and all other substances are classed as matter. Matter, then, is any material of which things are made, or which occupies space.

Matter is divided into two classes, *organic,* and *inorganic.* Organic matter has or once had life. All living animals and plants, with the substances they produce, are organic matter. Flesh, wood, flour, linen and leather are examples of organic matter. All substances which do not come from living things are inorganic

Underwood and Underwood.

NIAGARA FALLS IN WINTER, SHOWING DIFFERENT FORMS OF MATTER

matter. Water, air, stone, gold and iron are examples of inorganic matter.

States of Matter.—Matter exists in different forms. We are familiar with water as we see it in a pond or in a dish. It can easily be poured from one container to another. We call it a *liquid.* A liquid is a freely-moving fluid which tends to take the shape of its container.

If heated sufficiently, water boils, changes to steam and passes off into the air. Steam can be kept in a bottle, but the top must be covered tightly and the temperature of the bottle must be kept high enough to prevent the steam changing back to water again. Steam is a *gas.* A gas is a light, air-like substance which tends to expand indefinitely.

If a pail of water has been left where the temperature is low enough, we notice that the water has changed to ice. Ice is a *solid.* A solid is a body so rigid that it will keep its shape when left without a container to hold it in place.

These three different conditions, liquid, gaseous, and solid, in which matter can exist, we call *states of matter.* It is believed that all matter could be made to exist in each of these three forms by adding or removing sufficient heat. As yet, however, man has been unable to produce the degree of heat or cold necessary to change the state of certain substances.

Properties of Matter.—A *property* of a substance is some peculiar quality it possesses. A property is either *physical* or *chemical.* A physical property is one that can be recognized by the senses. Taste, color, size, odor are physical properties. A chemical property is one that accounts for a change in the composition of the substance. Wood burns when set on fire and is changed to ashes and gas. The ability to burn is a chemical property of wood.

A property of matter may be *general* or *special.* It is a general property when it is common to all kinds of matter, whether in solid, liquid or gaseous state. It is a special property when it shows itself in one or more kinds of matter but not in all kinds. All kinds of matter take up room or space. This is a general property commonly called *extension.* For example, water, whether

in a solid, a liquid or a gaseous state, occupies some space. Some, but not all, kinds of matter seem hard when touched. A piece of iron is hard as compared with an ordinary rubber eraser. Hardness, then, is a special property of iron.

Among the many other special properties of matter are brittleness, elasticity and flexibility. An object is brittle when it is easily broken into pieces. Glass and porcelain are brittle. An object is elastic when it readily resumes its original shape after some force has changed it. A rubber band is elastic. An object is flexible when it permits a good deal of motion of its parts without breaking. A whip is flexible.

Inertia and Gravitation.—*Inertia* and *gravitation* are important general properties of matter. Inertia is the tendency of a body when at rest to remain at rest, or when in motion to continue in the same motion unless prevented by some outside force. The inertia of a pen lying on a card on a table tends to make it remain on the table when the card is snapped away. Inertia tends to make one's body continue to move forward when a car in which one is riding suddenly stops. The heavier a body, the greater is its inertia. Think how much easier it is to roll a small stone than a large rock, or to stop the rolling stone than to stop the rolling rock. This is because the heavier rock's inertia is so much greater than the lighter stone's inertia.

Gravitation is the tendency of bodies to move toward each other. Every portion of matter in the universe attracts every other portion. No one knows what causes this. When this attraction draws objects toward the center of the earth it is called *gravity*. The measure of the amount that gravity attracts an object is the object's weight. A ball of iron dropped from ten feet above the ground falls because the earth attracts it; but in turn the iron attracts the earth. Each moves to meet the other, but the inertia of the heavier body prevents it from moving as much as the lighter one. Consequently, the much heavier earth hardly moves at all.

Conservation of Matter.—Near the close of the eighteenth century a great scientist, named Lavoisier, discovered that matter, although often apparently destroyed, continues to exist in some

form. Since his day, many experiments have tended to confirm the truth of this discovery, and now it is universally admitted that matter cannot actually be destroyed. This fact is known as the *conservation of matter*. The law may be stated as follows: "Whenever a change in the composition of a substance takes place, the amount of matter after the change is the same as before the change." The changes in matter which you see every day, such as the burning of wood or coal, in no way increase or decrease the amount of matter in the world.

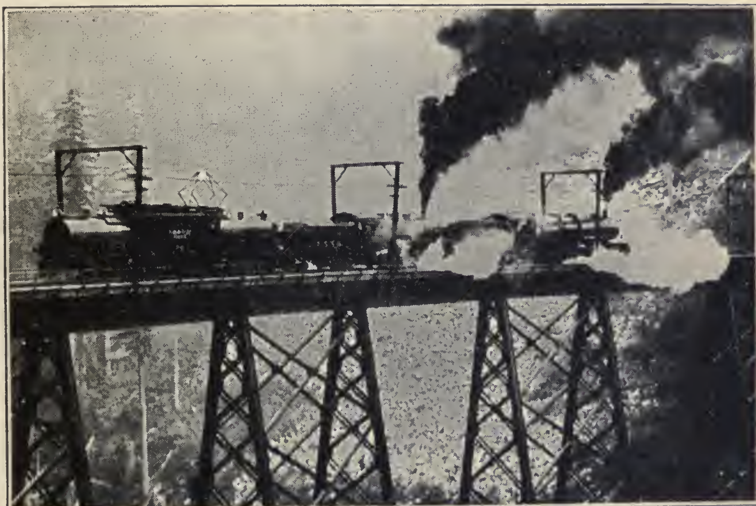
The most striking characteristic of matter is that it is constantly subject to change in appearance and in composition. This change may be rapid, as when the foundations of a building give way, or slow, as when a body breaks up piece by piece, like the wearing out of the floors on which we walk. These are examples of *physical changes,* because the material is not changed. The fine particles that are torn away are the same material. The wood that disappears from the floor in the form of very fine particles still remains wood.

There are changes, however, which affect the nature of the material. These changes, also, may be very rapid, as in the case of a burning building, or slow, as in the case of gradual decay. These are examples of *chemical changes* because the material is actually changed to form new substances. When wood is merely broken it is still wood, but when it is burned it is no longer wood. All living matter is especially liable to chemical change.

Forms of Energy.—Any change is always the result of the action of some force, and every force is dependent on some form of energy. Energy is the ability to do work, or to cause something to happen. Like matter, it exists in different forms. Thus, for example, it may appear in the forms of motion, heat, light, or electricity. Any one of these forms of energy may be changed into other forms, but no energy is either created or destroyed. This fact is known as the *conservation of energy.* It was one of the great discoveries of the nineteenth century, and is constantly applied in various ways.

The form of energy which is most apparent to us is the energy of motion, as shown in a speeding train, a moving football, a

bullet shot from a gun, or in falling water. The energy of motion is known as *kinetic energy.* Kinetic is a word of Greek origin and means moving. Energy may exist and not be active; then it is known as *potential* or latent energy, that is, energy that may, under proper conditions, become active. Potential is a word of Latin origin and means possible. A body of water in a high place has potential energy; a boy's muscles have potential energy; an elastic bow has potential energy; a bin of coal contains potential energy. When water falls, its energy becomes



Brown Brothers.

A CONTEST BETWEEN TWO FORMS OF ENERGY
The electric engine won over the two steam locomotives.

kinetic. When a boy kicks a football, the energy in the leg muscles becomes kinetic and is shown in the form of motion. When coal burns, its energy ceases to be potential and is manifest in the form of heat. Energy stored in any way may, under proper conditions, become active. Energy is necessary for the doing of the daily tasks of every person and, in fact, for all forms of life. It is important to remember that without the effects of energy on matter there would be no life.

Experiment to Illustrate the Transformation of Energy.—That heat is readily transformed into motion is easily demonstrated by an experiment with a radiometer and a match. Place an unlighted match near the glass globe of a radiometer and observe that it has no effect on the instrument. Then light the match and hold it near the globe. Observe what happens. Heat, which is one form of energy, has been transformed, or changed, into another form, that of motion.

In order to prove that the motion is not caused by the light from the burning match, heat a piece of iron and hold it near the bulb of the radiometer.

A RADIOMETER
The energy of heat is transformed into the energy of motion.

Other Illustrations.—In a locomotive engine, the energy stored in the fuel is changed by burning into heat energy. This heat energy is transferred to the water in the boiler and changes it into steam. The energy freed by the expansion of the steam in the cylinder is transformed into the energy of motion. The steam causes the piston to move back and forth. The piston rod carries this motion to a crank, which turns the driving wheel. The result is that the engine moves.

In a power plant, such as may be seen at Niagara Falls, potential energy already exists in the mass of water at the crest of the falls. The water falling onto the wheels of the power plant below causes them to revolve, and potential energy is transformed into the kinetic energy of motion. In turn, these wheels drive dynamos in which the energy of motion is transformed into the energy of electric currents. These currents are carried by wire cables to various cities, where they are employed in running trolley cars and in providing motor power for many industries. Electric energy is thus changed back to the energy of motion. According to the principle of the conservation of energy, the work which gravity accomplished in causing the water to fall upon the wheels is precisely equal to the work accomplished by all the electric cur-

rents developed, plus the heat energy given off, but not destroyed, by the wires and machinery.

Source of Energy.—Since all matter, whether animal, vegetable or mineral, must have energy in order to change in any way, it is important to know where that energy comes from.

The *sun* is the source of all the energy on the earth. Fuel, food, water and wind all derive their energy from the sun's rays.

International Paper Co.

THE ENERGY OF STEAM AND THE ENERGY OF FLOWING WATER RUN THIS FACTORY

The beds of coal from which so much heat energy is obtained represent the work of the sun in past ages in making the vegetable matter which in time became coal. By the aid of the sunlight, energy is stored in the food which man, animals and plants use. In our bodies much of the energy stored in the foods we eat is utilized as heat, motion and nervous force. Every muscle, like an engine, does work in transforming stored-up energy into

the energy of motion. But neither our bodies, nor any other living things, can develop more energy than already exists in some form in the materials taken into them.

The Basis of All Science.—We have just read about matter and energy. Remember that nothing exists, whether it be a stone, a plant, or an animal, that is not made of matter. Remember, too, that any change, such as of position, shape, size, color, temperature, can never be brought about without the use of energy. Matter and energy are all that are needed to make up the entire earth, everything on it, and even all growth and motion.

SUMMARY

All substances consist of matter which is either organic or inorganic.

Matter occurs in three states, gaseous, liquid and solid.

A property of matter is some quality of that matter.

A property may be general or special, physical or chemical.

The law of the conservation of matter declares that matter can never actually be destroyed, though it can be changed from one form to another.

The most striking characteristic of matter is the fact that it is constantly subject to changes. These changes are either physical or chemical. In a physical change the nature of matter remains the same; in a chemical change it is altered. All living matter is especially subject to chemical change.

Changes in matter are brought about by the action of some form of energy, such as heat, light or motion.

The law of the conservation of energy declares that energy cannot be created or destroyed, although it may change its form.

All living things must have energy in order to live.

The source of all energy is the sun.

Fact and Thought Questions

1. Define matter. State the difference between organic and inorganic matter.
2. Give several examples of inorganic matter seen on the way to school.
3. Name several examples of organic matter in the classroom.
4. Define states of matter.

5. What material have you seen in more than one state of matter?
6. What are properties of matter?
7. Name two general properties of three objects in the classroom.
8. Name special properties of each of three objects in your home.
9. Complete the following statements:
   (a) Wood is a good building material because of its property of ——.
   (b) Steel is used for rails and bridges because of its property of ——.
   (c). I look for the property of——in a good dress material.
10. What is the law of conservation of matter?
11. Define inertia.
12. Why is it hard to stand in the aisle of a trolley, without support, when it rounds a sharp curve?
13. Define (a) gravitation; (b) gravity.
14. How much would a ten-pound iron ball weigh if there were no gravity?
15. What is energy?
16. With your hand, illustrate the energy of motion.
17. Name another form of energy your body illustrates.
18. What forms of energy are illustrated by an automobile?
19. Explain the law of the conservation of energy, giving an illustration from common things about you.
20. What is the source of all energy?
21. What forms of the sun's energy do we notice every day?

Projects

1. Perform an experiment of your own to illustrate a physical change of matter.
2. List, with a proper heading, ten examples of the effects produced in your own home by different forms of energy.

Outdoor Observation

1. Observe and list forms of energy noted on your way to and from school.
2. Observe and list five kinds of matter, and name several properties of each kind.

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Introductory Physics .... *Higgins*
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CHAPTER III

THE COMPOSITION OF MATTER

Here is an interesting fact. If you were asked to make a list of the materials found in the things you see about you every day, it would take hours and hours, and the list would be very, very long. But if a scientist gave you a list of all the basic kinds of matter in the world, there would be only about ninety. How is that? How can there be only ninety kinds of original matter and thousands of materials?

The Molecular Theory.—Through their study and experiments scientists have learned some startling things about matter. They have worked out what is known as the *molecular theory* which tells us that substances are made up of countless tiny particles or bits of matter. The *very smallest bit* into which a substance can be broken up and still be the same kind of substance, they call a *molecule.*

A molecule is so small that it cannot be seen even with the aid of the microscope, and no scales are fine enough to weigh it. Moreover, these molecules are never still. They are always in continuous motion or vibration one against another even in the hardest of materials. The rate at which these molecules vibrate varies with the temperature. The more an object is heated, the faster these molecules vibrate.

The Atomic Theory.—Most substances are made up of different kinds of material. When a molecule of such a substance is broken up into particles of the material of which it is composed these particles are called *atoms.* These atoms are not like the molecules from which they are taken.

The *atomic theory* was formed in the beginning of the nineteenth century by John Dalton, an Englishman, though the idea had long existed in a crude way in the minds of thinking men. The theory assumes that atoms of the same substance have the same weight and that different kinds of atoms

unite with each other in certain fixed proportions to form molecules of different kinds of matter.

Now let us use our imagination and try to picture a molecule of water. Scientists tell us that this molecule of water is composed of two atoms of a gas called hydrogen and one atom of a gas called oxygen. These particles or atoms of oxygen and hydrogen cannot be divided into other kinds of material. Water, then, must be made up of these two substances. Substances which cannot be broken up into other kinds of matter we call *elements.*

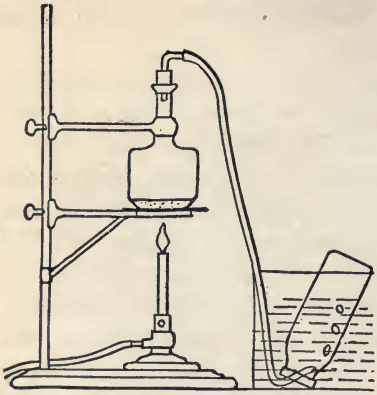
By means of electricity, it is possible to separate a molecule of water into its two elements, hydrogen and oxygen. When these elements separate, the water vanishes, and in place of a molecule of water we have two atoms of hydrogen and one atom of oxygen. Substances which, like water, can be divided into elements, we call *compounds.* According to the atomic theory, which is accepted by scientists as true, the molecules of all compounds are made up of atoms in various proportions.

Having learned that an element is a substance which cannot be broken up into anything simpler, we shall now take up the study of some of the most common of them. Before beginning such a study, we must first collect or prepare the elements to be studied.

Oxygen.—Oxygen is a gas, named by Lavoisier. He discovered that it exists as an element in air and in many compounds, and that it is the true cause of burning. It is the most widely distributed element. One-third of water, about one-fifth of air, and a large per cent of the crust of the earth are oxygen. It is absolutely necessary to all life. The most important characteristic of oxygen is its ability to sustain combustion, that is, to produce heat and light when it unites with other elements.

Experiments with Oxygen.—

Preparation of Oxygen.—Mix equal parts of manganese dioxide and potassium chlorate in a flask. Close the opening of the flask with a rubber stopper through which a bent glass tube passes, the other end of the tube reaching under the surface of water in a tray. Place an inverted bottle filled with water over that end of the glass tube which is in the water, being



Collecting Oxygen

careful to keep the opening of the bottle covered until it is under the surface. Heat the mixture in the flask and a gas, oxygen, will be given off. This gas will gradually fill the bottle, replacing the water. Cover the mouth of the bottle under water and stand it right side up on the table.

Oxygen also is made by bringing oxone (sodium peroxide) in contact with water. Place a piece of oxone the size of a hickory nut under water and collect the gas in a bottle.

Chemical Action of Oxygen.—Insert a glowing splinter into the oxygen and observe the result. This result is *oxidation* by the chemical union of oxygen with carbon, an essential part of the splinter. The chemical union of any substance with oxygen is oxidation. The most important chemical property of oxygen is its power to make matter oxidize, or burn.

Other Properties of Oxygen.—By use of the senses of sight, taste and smell, find other properties of oxygen. These are physical properties.

Hydrogen.—Hydrogen is a gas. Its most important characteristic is that it will combine with oxygen to form water. An important physical characteristic is its extreme lightness, because of which it is extensively used in airships to make them lighter than the air.

Experiments with Hydrogen.—

Preparation of Hydrogen.—Use a flask with a stopper having two holes, through one of which passes the small end of a thistle tube reaching nearly to the bottom of the flask, and through the other of which passes a short bent glass tube. To the outer end of the bent glass tube attach a rubber tube long enough to reach beneath the surface of water in a tray. Place pieces of zinc in the flask and pour through the thistle tube sufficient dilute hydro-

chloric acid to cover the lower end of the tube. Collect the gas which will be made, by allowing it to pass through the rubber

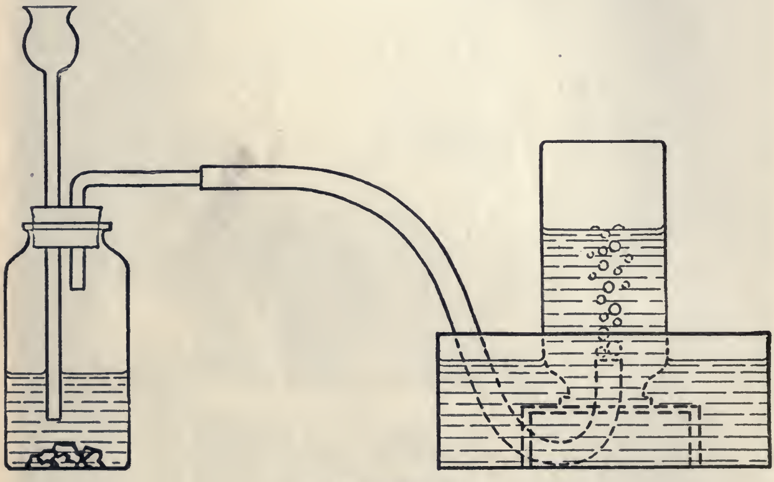
National Welding Equipment Co.

OXY-ACETYLENE WELDING

A mixture of oxygen and acetylene gas whose flame is so hot that it melts and fuses the toughest metals.

tube leading from the flask into a water-filled bottle inverted in the tray. Test this gas. It will be found odorless, tasteless and colorless.

Production of Water.—When hydrogen unites with oxygen, water is formed. To show how water is formed by the oxidation of hydrogen, pass hydrogen from the generating flask through a tube containing calcium chloride to absorb all moisture present. After passing the hydrogen through this substance, allow it to enter a glass tube ending in a narrow opening. **Caution:** *Care should be taken at this point to test the gas for purity, or freedom from air, because hydrogen and air form a very explosive mixture. This test may be safely made with a small amount of the gas in a test tube around which a towel has been wrapped.*



Preparing Hydrogen

Quickly bring the mouth of the tube to a Bunsen flame. If air be present, a loud report will result. If no air is mixed with the hydrogen, only a slight report will be heard, and a bluish flame will be noted. When the hydrogen has been proved pure, hold a glass plate in the escaping gas and notice if water is formed on it. Then hold over the flame a thoroughly dry cold tumbler, and observe what occurs.

Carbon.—Carbon is a solid. It is the main element in organic matter, and an essential part of all living things. At ordinary temperatures it is inactive and so will not unite readily with

other elements. At higher temperatures it combines very readily with other elements, especially with oxygen. This fact we have already observed in the burning or oxidation of the wood splinter in oxygen.

There are three forms of carbon: diamond, graphite and charcoal. These have certain characteristics in common, three of which may be noted by the study of charcoal, which is nearly pure carbon.

Experiments with Carbon.—Light a match. It will burn; that is, the carbon in the wood will unite with the oxygen in the air, and heat and light will be produced. Blow out the flame before the match is consumed and the black material left is charcoal. By testing, it will be found tasteless and odorless. Light the charcoal of the match again. Hold your hand over it. You will discover that heat is given off. Charcoal, then, will burn and produce heat. It is a solid and is odorless and tasteless. These last three properties are characteristics of all three forms of carbon.

Nitrogen.—Nitrogen is a gas found in the air, of which it forms nearly four-fifths. It is also found in combination in a large number of substances. With other elements, it forms a part of animals and of plants.

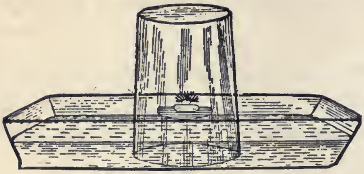
The most striking characteristic of nitrogen is its inactivity. It neither burns nor supports combustion. To prove this, thrust a burning match into a bottle of nitrogen and observe the result.

Experiments with Nitrogen.—

Preparation of Nitrogen.—The air is made up largely of nitrogen and oxygen. To obtain nitrogen, it is necessary to remove oxygen from the air. The most convenient way is to burn a small piece of phosphorus in a bell jar over water. The oxygen is consumed in the burning, leaving the nitrogen.

Another way is to place a wide-mouthed bottle over a burning candle that is fastened to a piece of cardboard floating on lime water. When the candle ceases to burn, it shows that the oxygen has been consumed. The bottle should then be turned right side up, closely covered so as to retain the lime water that has risen to take the place of the oxygen. By shaking the contents

of the bottle, the lime water will absorb the carbon dioxide given off by the burning candle, and the nitrogen will be left in the bottle. Air must not be allowed to mix with the nitrogen. This may be prevented by keeping the opening of the bottle covered. The student will find that the gas is colorless, odorless, and tasteless, and that it will not burn or support combustion.



COLLECTING NITROGEN

Elements of Which Matter is Composed.—There are about 90 known elements of which matter is composed. The table below, for reference only, gives the names of some of the more common elements, where they are found, the symbols which stand for them, and some of their properties and uses.

Name and Symbol	*Where Found*	*Properties*	*Uses*
Aluminum (Al)	Earth in combination with other substances	Solid, very light, stiff, strong tin-white metal	Used in manufacture of cooking dishes and airplane and automobile frames
Calcium (Ca)	Rock, soil and other substances	Solid, soft, light	Forms a part of many useful compounds, as lime and gypsum. Necessary in plant and animal tissues
Carbon (C)	Organic tissue, coal, wood, etc.	Solid, insoluble, burns forming the gas CO_2	Forms part of all nutrients and organic tissues; used as fuel
Chlorine (Cl)	Found only in combination with other substances, mostly metals	Gas, greenish-yellow, has a suffocating odor, an active element, heavy	Used as a bleaching agent and a disinfectant; forms a part of several acids
Chromium (Cr)	Found only in combination with other substances	Grayish white, hard, brittle, difficult to fuse	Used for plating other metals to prevent their tarnishing, and for combining with steel to make a hard alloy
Copper (Cu)	Found in rocks in combination with other substances, also in a free state.	Heavy, reddish color, tough, strong, good conductor of electricity	Used for electrical purposes, for roofs and for making alloys such as brass
Gold (Au)	Found in quartz rock and in sands of rivers	A heavy yellow substance, quite soft, good conductor of electricity	Used for coin, plate and jewelry when mixed with a little copper or silver to give it hardness.

Name and Symbol	*Where Found*	*Properties*	*Uses*
Hydrogen (H)	Found in water, animal and plant tissue and in all acids	Gas, colorless, odorless, tasteless, very light, burns but does not support combustion	Forms part of all organic tissues and all foods; used in airships
Iodine (I)	Found in Chile saltpeter and in ashes of seaweeds	Solid, heavy, purplish-black, shiny, slightly soluble in water	Used for medicinal purposes and in making dyes and drugs. A test for starch
Iron (Fe)	Ores and soils	Solid, heavy, grayish-white, oxidizes readily	Used in building; necessary to plants in making food and to animals for red corpuscles
Lead (Pb)	Ores, especially galena ore	Solid, bluish-gray color, heavy, becomes dull in air, soft, easily fused	Used for lead pipes, in making oxides and in alloys
Magnesium (Mg)	Rock, soil and other substances	Solid, soft, light, white, easily dissolved in acids	Compounds necessary in animal and plant tissues; used in alloys
Mercury (Hg)	Usually found in ores	Fluid, white, heavy, shiny, becomes solid in extreme cold	Used in making scientific instruments such as the barometer and thermometer
Nickel (Ni)	Found only in combination with other metals.	Gray, not much affected by air	Used in making German silver and for coins
Nitrogen (N)	Air, soil, nitrates, protein	Gas, colorless, odorless, tasteless, inactive, does not burn or support combustion	Forms nitrogen compounds for soil and all living tissues; dilutes oxygen of the air
Oxygen (O)	Air, water, soil, animal and plant tissue	Gas, colorless, odorless, tasteless, soluble, very active, causes substances to burn	Releases energy; causes decay
Phosphorus (P)	Mineral compounds, phosphates, bones. Never occurs free in nature	Solid, yellow, burns readily, very poisonous	Used in making matches; necessary in seeds, nerve and bone tissue
Platinum (Pt)	Found in small grains in the sand of certain rivers	Solid, very heavy, very infusible, silvery appearance, not attacked by common acids	Used to make chemical dishes, such as crucibles, required to stand high temperature; in jewelry and in other ways
Potassium (K)	Rock, soil and other substances	Solid, soft, light, reacts violently with water, soluble in acids.	Compounds necessary in plant and animal tissues
Silicon (Si)	Most abundant element next to oxygen; forms ⅙ of the mass of the earth	Hard, inactive toward reagents	Used in making glass

Name and Symbol	*Where Found*	*Properties*	*Uses*
Silver (Ag)	Usually found in ore, sometimes in a free state	Heavy, rather soft, solid, white, best conductor of heat and electricity	Used for coin, plate and jewelry when mixed with a small portion of copper; compounds used in photography
Sodium (Na)	Rock, soil and other substances; occurs principally in nature as common salt	Solid, soft, reacts violently with water, soluble in acids	Compounds are used for various purposes, medicine, fertilizers etc.; necessary in plant and animal tissues
Sulphur (S)	Mineral compounds and proteins	Solid, yellow, insoluble in water, tasteless, melts at a low temperature	Used in making gunpowder, matches, commercial rubber, and acid; necessary in bone and other tissues
Tin (Sn)	Found in ore in combination with other substances	Soft, white substance with silver-like appearance, can be rolled into thin sheets	Used in many ways such as in roofing, in making cans and cooking dishes
Zinc (Zn)	Found as ore in combination with other substances	Heavy, bluish-white, shiny, dissolves readily in nitric acid.	Used as lining for water tanks, in electric batteries and in making alloys

Many elements such as gold, platinum, radium and helium, are found only in small quantities. For this reason they are called rare. The number of elements of which common things are composed is less than one-fifth of the elements known. Among those most widely distributed and which form the greatest part of the earth's crust are oxygen, silicon, iron, aluminum, calcium, magnesium and potassium. All living things are made up largely of carbon, hydrogen, oxygen and nitrogen.

Compounds and Mixtures.—All substances are classed as (1) *elements,* (2) *compounds,* or (3) *mixtures.* A compound is a chemical union of two or more elements, a union in which each element loses its own properties and helps form a new substance having entirely different properties. The gases oxygen and hydrogen unite chemically and form a liquid, water. Water is a compound.

A mixture is a physical union of two or more substances which do not lose their properties by uniting. What is known as a *solution* is also a mixture. A cup of sweetened coffee is a solution or a mixture, but not a compound. In it there are

particles of water, of sugar, and of the material from coffee that gives flavor. These are all distributed in this mixture, but do not unite to form a new substance. Each keeps its own properties.

Air is a mixture made up of four or more kinds of gases. Oxygen, nitrogen, carbon dioxide and water vapor all exist in air as separate gases, but they do not unite chemically to form a new substance.

Water.—Water is a most important inorganic compound and should receive special attention. It is made up of particles of hydrogen and oxygen which have united to form the new substance. Water in a pure state is tasteless and odorless. It will not burn. It is a solvent; that is, it has the power of dissolving many solids. These, when placed in water, apparently disappear, but really are only changed to a liquid form and are said to be held in solution. This ability to hold substances in solution is a most important characteristic of water.

It is hardly necessary to draw attention to the wide distribution of water, yet water is found in forms and under conditions which may prevent its immediate recognition. Never forget that all living things contain a large proportion of water. All foodstuffs contain water. This may be proved experimentally by collecting the water vapor produced when a piece of any foodstuff is heated.

Carbon Dioxide.—Another very important inorganic compound is carbon dioxide. This colorless gas is found everywhere in the air. It is formed constantly in burning, in decay, and in the breathing of animals, and is then spread or diffused through the air. It will not burn and does not support combustion.

Experiments with Carbon Dioxide.

Preparation of Carbon Dioxide.—Put pieces of limestone or marble into a flask and pour hydrochloric acid on them. This will release the carbon dioxide in the limestone. Collect several bottlesful of this gas by the use of a bent glass tube passed through the stopper of the flask and arranged as for the collection of oxygen.

Insert a burning splinter into one bottle and observe the result. Insert other burning substances and observe the results. Pour

the gas from a bottle on to the flame of a burning splinter and observe what happens.

That carbon dioxide is formed in the process of breathing may be shown by forcing the gases from the lungs through the mouth into a glass of lime water, by means of a tube. The lime water will assume a milky appearance showing the presence of carbon dioxide.

SUMMARY

The molecular theory of matter assumes that every substance is composed of minute particles called molecules. A molecule is the smallest particle of matter that can exist alone and still keep the same properties as the substance from which it came.

The atomic theory assumes that molecules of substances are composed of particles, much smaller than molecules, called atoms.

An element is a substance which cannot be broken up into anything simpler.

The four most important elements are oxygen, carbon, hydrogen and nitrogen.

The most important characteristic of oxygen is its power to support combustion.

Carbon is an essential part of all living things. At a high temperature, it unites readily with oxygen, releasing energy in the form of heat. It is tasteless and odorless.

The most important characteristic of hydrogen is that it will unite with oxygen to form water. It is a colorless, odorless and tasteless gas.

The striking characteristic of nitrogen is its inactivity. It is a colorless, odorless and tasteless gas. It forms a part of the air we breathe, of most organic matter, and of many other substances.

A compound is a chemical union of two or more elements. Water and carbon dioxide are important compounds.

A mixture is a physical union of two or more substances and does not change the character of any of them.

Water is a solvent. It is not combustible. It is tasteless, odorless and, in thin layers, is colorless. It is widely distributed. It forms a large part of all living things.

Carbon dioxide, a colorless gas, will not burn, and does not sustain combustion. It is formed in burning, in decay and in respiration.

Fact and Thought Questions

1. What is the molecular theory?
2. What is the atomic theory?
3. Define an element. Name several elements with which you are familiar.
4. Name the four most important elements.
   (a) Which of these four are tasteless and odorless?
   (b) Which support combustion?
   (c) Which are essential to life?
5. Name several elements used in household articles.
6. Complete orally the following statements:
   (a) If I drink a glass of water, I drink the elements ——.
   (b) A compound is ——. —— is an example of a compound.
7. Define a mixture.
8. Define a solution.
9. Name several mixtures common in the preparation of food.
10. Name some material you can add to salt and have a mixture.
11. Suggest a material to add to water to form a solution.

Projects

1. Burn a match. List, under a proper title, all the facts your senses tell you in regard to it.
2. Prepare a list of the various elements you have seen and can recognize. Name several articles or substances in which each appears.
3. Bring to class and be prepared to describe the main characteristics of (a) an element; (b) a compound; (c) a solution.

Outdoor Observation

1. Explore a neighboring field or yard for compounds and mixtures. Secure one sample of each group and label it properly.

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CHAPTER IV

THE AIR WE BREATHE

We are living at the bottom of a great invisible ocean—an ocean of air. We can often feel the movements of its currents as they sweep about us. At times, its wind-waves are even more violent than the storm billows of the sea. In this air ocean, birds dart about, just as fish swim about in the water. Great airships sail through it. This air ocean is valuable to us in many ways, but most important of all it makes life itself possible. Without air all forms of animal and vegetable life would quickly die. The earth would become a barren waste, just another dead moon in the heavens.

Air is a mixture of several gases. It is one of the most common forms of matter. It occupies a vast amount of space, extending upward several miles above all parts of the earth. It is commonly spoken of as the *atmosphere.* Air is also found in water and in soil.

Experiments to Show the Presence of Air in Water and in Soil.—To show that air is found dissolved in water, it is only necessary to heat water gradually in a beaker or other dish. Long before the water becomes hot enough to boil, small bubbles may be seen coming from the bottom and breaking at the surface. These bubbles are air escaping from the water. If heated long enough nearly all the air escapes. Perhaps you have noticed that boiled water is tasteless. This is largely because of the absence of dissolved air.

To show that air is found in soil, pour water on garden soil in a pan until the soil is soaked and a thin layer of water lies on top of it. Bubbles will be seen rising from the soil. They show that air is escaping; so we may conclude that air is found in soil.

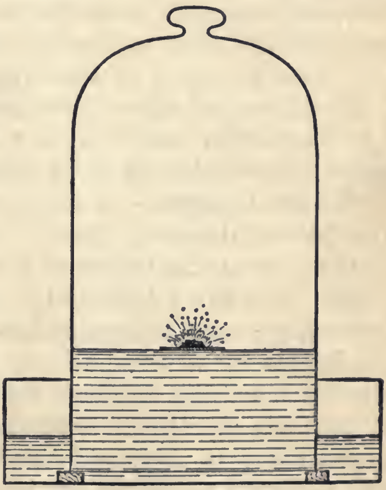
Composition of Air.—Air is composed, or made up, largely of *oxygen* and *nitrogen,* with a small amount of *carbon dioxide, water vapor and gases* called *argon, neon* and *krypton.* It is com-

monly estimated that 78% of the air is nitrogen, 21% oxygen, and the remaining 1% the other gases which are of little importance to us here. Most air also contains microbes, or germs, and particles of dust; these, however, are not found in pure air.

Properties and Uses of the Parts of Air.—Certain of these gases which make up the air have properties and uses so important to our welfare as to deserve special study at this time.

Oxygen.—The most important property of oxygen is that it will support combustion or burning. This is a chemical property. Other properties are that it is colorless, tasteless and odorless. These are physical properties.

The most important value of oxygen is in respiration. During both day and night we breathe about sixteen times each minute. The air we breathe in provides oxygen for all parts of the body. But respiration means more than breathing. It includes the work oxygen does in burning up the foods we eat. This burning releases heat, part of which keeps the body warm and part of which provides the energy necessary to carry on life. Oxygen performs a similar service for all animals and all plants.



Removing Oxygen from the Air by Burning Phosphorus in a Water-sealed Bell Jar

Experiments to Show Oxygen in Air.—It is an interesting experiment to show the presence and the proportion of oxygen in the air. You can test for its presence by lighting a candle. If it continues to burn there is oxygen in the air.

To find the proportion of oxygen in air burn a small piece of phosphorus under a bell jar over water. The burning of the phosphorus will use up the oxygen and leave the nitrogen. Water will rise in the jar and occupy the space of the oxygen. By

measuring the height to which the water rises in the jar the proportion of oxygen that was in the air in the jar may easily be discovered.

Nitrogen.—One important property of nitrogen is its inactivity. It does not readily unite chemically with other elements. Like oxygen, it is colorless, tasteless and odorless. Nitrogen is especially useful in the air in diluting or diminishing the power of oxygen to burn other substances. The nitrogen in air serves the same purpose as water does when it is mixed with lemon juice to lessen the sour taste. If air were pure oxygen it would be so active and so powerful that it would destroy all animal and plant life. A fire once started would rapidly oxidize all material with which it came in contact, for even such material as iron will burn in pure oxygen.

All living things need nitrogen for making the tissue of which their bodies are formed, but most of them are not able to use it as found in the air. It must first be united chemically with other substances. Certain microscopic forms of plant life, called bacteria, have the ability to take nitrogen from the air and to change it into a form that when in solution the roots of plants can absorb. The plants then make it into a food substance, called *protein,* which is essential to all living things.

Carbon Dioxide.—As a separate gas, carbon dioxide is heavier than air and therefore tends to settle into its lower layers. It is so heavy that it can be poured from one container to another like water. It will not burn and nothing will burn in it. On this account it is used in fire extinguishers. It sometimes settles in the bottom of wells, mines, or low, unventilated cellars. As one cannot live long breathing carbon dioxide alone, it is dangerous to enter any place where large quantities of it have collected. Its presence may be detected by putting a small pail of lime water into the space where the gas is supposed to be. If it is there, the lime water will assume a milky appearance. A lighted lantern is sometimes used for the same purpose. If present, the gas will cause the light to go out.

Water Vapor.—Water vapor or moisture is usually present in air. Its presence may be detected by placing a pitcher of cold

water in a warm room. The water vapor will condense and settle in drops of moisture on the outside of the pitcher.

Moisture is absolutely necessary to the life of plants, animals and man. If there were no moisture in the air there would be no rain, and consequently plants would cease to grow and produce food. If this should happen, all living things would starve, and there would be no life on the earth.

The Relation of Air to Health.—Air is called good or bad according to its effect on health and feelings. Air is considered good when it contains the proper amounts of oxygen and water vapor. We all recognize the bracing effect of a walk outdoors where there is plenty of fresh air. Such air is good. Air becomes bad when it is rebreathed several times in a close, over-heated room where there is too much moisture and no circulation. Odors from the body in such a room also aid in making the air bad. Such air is more likely to contain disease germs.

Air is used by all living things. All living things are adapted for securing air. Air may be taken from the water, in which it is dissolved, by water animals and plants.

Proper Methods of Breathing.—Proper methods of breathing are essential to good health. A good way to show these methods is to have each member of a class stand erect with hands on the hips and thumbs toward the back. Keeping the mouth closed, each one should inhale air through the nostrils, until he feels the thumbs rise. This will cause the diaphragm, the muscle between the chest and the abdomen, to contract and allow deep breathing. Then exhale the air, that is, breathe it out gradually.

Still standing erect, with hands at the side and palms turned outward with thumbs back, inhale as before. This method will force the shoulders back and cause expansion of the chest. Then exhale the air as before and repeat the processes. Make a practice of deep breathing.

Properties of Air.—Among the important properties of air are that it will flow, is elastic, and exerts pressure. Although we seldom think of it, air is a fluid because it flows, and it has weight, because it exerts pressure. These properties account for many of the interesting things we note in connection with air.

One has only to observe the effects of wind to be convinced that air flows. That it is actually matter, a real substance which occupies space and exerts pressure, is not so apparent. Experiments, however, will show that these statements are true.

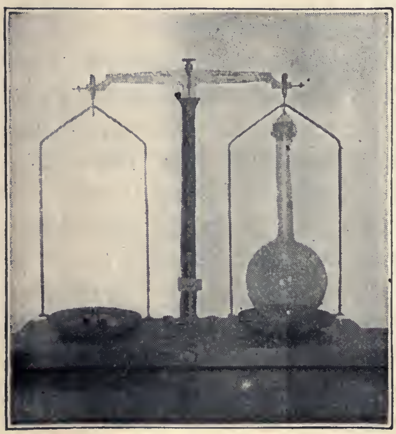
Experiments to Show Properties of Air.—To show that air occupies space, press an empty tumbler upside down into water. You will notice that it is not easy to fill the tumbler held in that position. Why?

Close one end of a piece of glass tubing about a foot long. Then insert the open end into a jar of water. Does water enter the tube? If not, why? Open the upper end of the tube, still holding it in the water. Does water rise in the tube? If so, what does it displace?

Blow air into an empty toy balloon and notice what happens.

After these experiments, do you conclude that air does or does not occupy space?

Hold in the hand a piece of thin board about two feet square and swing it edgeways through the air. Is there much resistance? Then swing the board broadside through the air. Is there more resistance than in the first case? If so, why?



Air Has Weight

To show that air exerts pressure, hold a glass tumbler under water so that the water completely fills it. Then place a sheet of cardboard over the opening of the tumbler under the water. Turn the tumbler bottom up, holding the cardboard close over the opening, and lift the tumbler from the water. Then remove the hand from the cardboard. Does the cardboard remain in place and the water in the tumbler? If so, why?

Again, take a tin can having a small opening in the center of the top, and another opening in the center of the bottom. Close

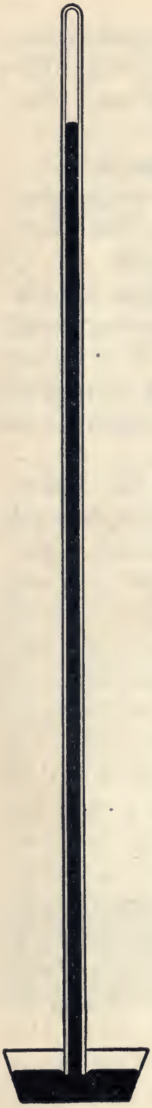
the lower opening with a cork. Then fill the can with water and close the opening in the top with a cork. After doing this, remove the cork in the bottom. Does the water run out of the can? Remove the cork in the top. What happens?

To show that air has weight, weigh on a delicate balance a large corked bottle. Exhaust from the bottle all the air possible by means of an air pump and weigh the bottle again. The difference shows the weight of the air that has been taken out.

The Barometer.—The pressure of the atmosphere at any place on the surface of the earth is liable to change owing to the movements of the air due to heating and cooling. The pressure also varies at different heights. Normally at sea level air presses with a force of nearly 15 pounds per square inch. It grows less as the height above sea level increases.

Evangelista Torricelli (1608-1647) believed that the atmosphere exerted a pressure on everything. To prove this, he used a glass tube a little more than thirty inches long, closed at one end. This he filled with mercury, put his finger over the open end that he might invert it without the mercury getting out, and placed this open end below the surface of some more mercury in an open dish. When he removed his finger, leaving the long tube in a vertical position with the lower end open and under the mercury in the dish, he found that the mercury lowered in the tube to a certain level and there it remained. He found, also, that it varied some from day to day. This, he thought, was due to a variation in the atmospheric pressure. He reasoned that if this pressure were due to the weight of the air, as he believed it was, the higher he took his apparatus the lower the mercury would settle in the tube. This he found to be true by carrying the apparatus up a mountain. As we know, the reason for the settling of the mercury in the tube as he went up the mountain was because the higher he went the less was the weight of the air on the mercury in the dish. At sea level, the weight of the atmosphere will support a column of mercury about 30 inches in height, or a column of water about 34 feet in height.

Torricelli's instrument and other instruments for measuring air pressure are called *barometers.* A barometer may be used to



A Mercury Column
It illustrates the principle of the mercury barometer.

measure height, such as the height of a mountain, or the distance of an airplane above the earth. When thus used it is called an *altimeter.*

Atmospheric pressure changes with the weather. In fact, the barometer starts to change its reading of atmospheric pressure before we can see or feel the change in the weather. At any fixed level a falling barometer (the pressure becoming less) indicates an approaching storm. A rising barometer indicates fair weather.

Experiments to Show Atmospheric Pressure.—To show that air exerts pressure upon surfaces because of its weight, fill a barometer tube about 36 inches in length with mercury. Place a finger tightly over the open end of the tube and invert it into a dish of mercury. Then, after fastening the tube to an upright standard, remove the finger, taking care that no air enters the tube. Does the mercury in the tube run into the dish? If not, why?

To show the effect of atmospheric pressure on a barometer, place a common mercurial barometer where it can be observed frequently for a week. Each day observe and record the reading of the barometer. At the end of the week plot a graph to show this record.

Some Simple Experiments to Arouse Thought.—Blow air into an empty football, a toy balloon or an automobile tire and notice that it fills out evenly. What does this indicate in regard to air pressure?

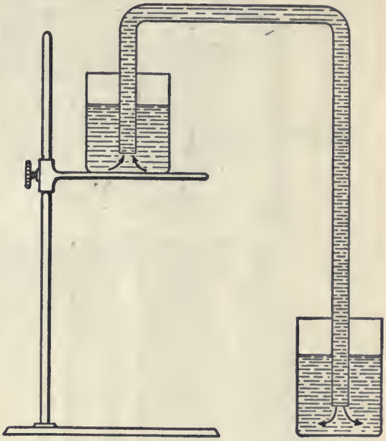
Fill with water a bent piece of tubing about 3 feet long and close both ends of the tube. Place one end in a pail of water on a table, and the other end in a pail on the floor. Then open both ends of the tube. Does the water run out of the upper pail? If so, why? A bent tube used in this way to drain liquid from one level to another is called a *siphon.*

Press the thumb into a rubber ball filled with air. Notice that a rubber automobile tire flattens a little when the automobile is heavily loaded.

What property of air do these facts show?

Light a candle and place it under a glass jar. It will soon cease to burn. What does this show?

The principle of air pressure may easily be shown by the use of a medicine dropper and a glass of water. Squeeze the bulb of the dropper after placing the open end in the water; then release the hold on the bulb. Account for what happens in the dropper. Apply this principle to the explanation of the use of a vacuum cleaner, a bicycle pump, a drain pipe cleaner, an airplane, your breathing.

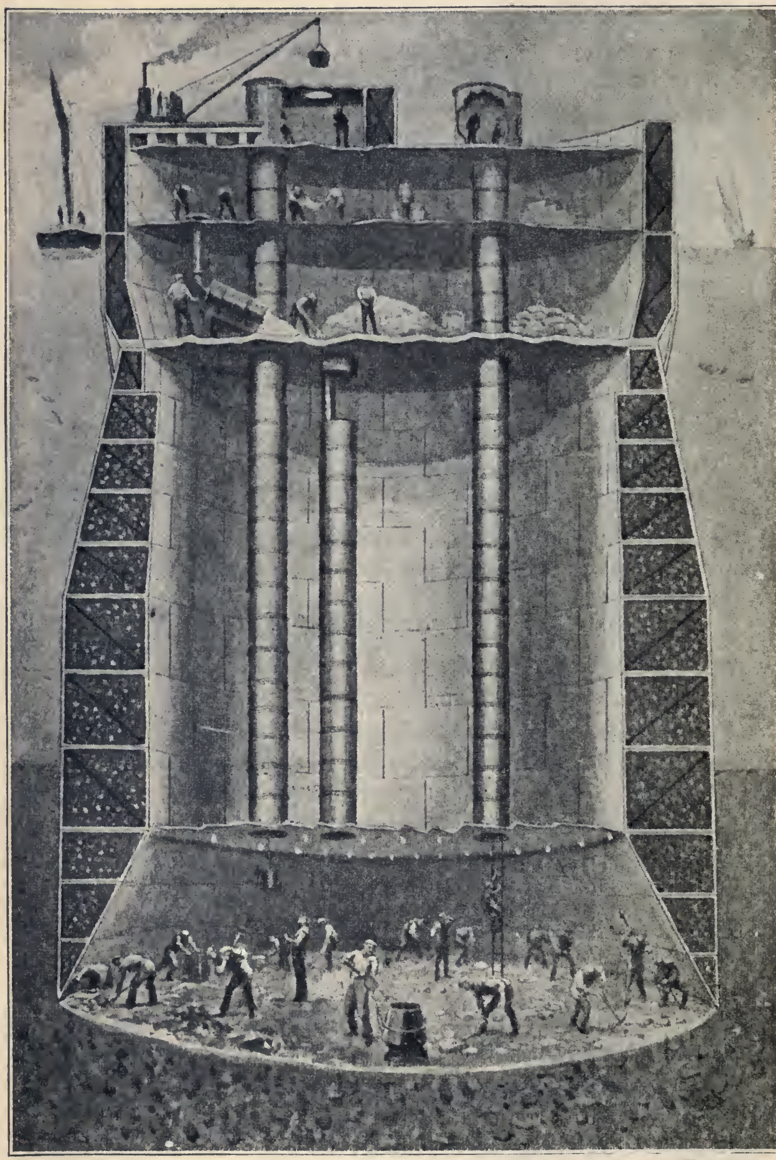


The Siphon

The air pressure at both levels is about the same, but the weight of water is less in the short arm than in the long arm. This causes water to flow down the long arm and up the short arm.

Some Practical Uses of Air Pressure.—The properties of air that have been illustrated by the experiments in this chapter are very important in doing many things that affect our lives. The less the volume into which a certain amount of air is compressed, the greater the pressure it will exert. The more air one pumps into an automobile tire the harder it becomes. If air is compressed to one-fourth of its original space, it will exert four times as much pressure as it did in its normal condition. It immediately regains its volume when the pressure is removed.

Compressed air is often used in setting brakes on railroad trains, automobiles, and buses. It has added greatly to the safety of travel. Compressed air is used to run machine drills, in tunneling and in mining. It is used to keep out mud and water from the box-like rooms, or *caissons,* in which men work under water or beneath the beds of streams. Large buildings are ventilated by forcing



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THE CAISSON. A GREAT WORKSHOP UNDER WATER

Air under pressure, admitted through special tubes, keeps out mud and water.

air into them under pressure or by pumping out the stale air so that atmospheric pressure will cause fresh air to enter to take its place. Mines are ventilated by air pressure. Air pressure also is used in many ways in various industries. Moreover, it is the natural pressure of the air that enables birds and other flying creatures, as well as kites and airplanes, to remain up in the air.

SUMMARY

Air is one of the most common forms of matter. It occupies a great space about the surface of the earth.

Air is composed largely of oxygen and nitrogen. Only one per cent of other gases is found in it.

Air possesses both chemical and physical properties and has many uses.

The most important property of the oxygen part of the air is that it will support combustion.

An important property of nitrogen is its inactivity. In the air it serves to dilute the oxygen. It is especially useful in the making of protein foods by plants.

An important property of carbon dioxide is that it will not burn or sustain burning. It is useful in putting out fires. It is dangerous to life if present in large quantities.

The amount of water vapor or moisture in the air varies at different times. It is necessary to both plant and animal life.

Air has an important relation to all life. Proper methods of breathing are essential to good health.

Other important properties of air are that it will flow and exert pressure. It is a real substance and has weight.

An instrument called a barometer is used to show the changes of atmospheric pressure.

The fact that air is elastic and can be compressed makes it useful in setting brakes on trains, automobiles, and buses, in pumps, in tunneling under streams and in many devices in factories.

Air pressure enables birds and other flying creatures to remain up in the air, and makes possible the flying of kites and airplanes.

Fact and Thought Questions

1. Where is air found? How can you tell there is air all about you?
2. Of what does air consist? In what proportions?
3. Of what special value to life is the oxygen in the air? Could one breathe pure oxygen?
4. What is the value of the nitrogen in the air?
5. Why is carbon dioxide dangerous in large quantities? How can you determine if it is present in dangerous amounts? Name some situation in which it would be wise to employ this test.
6. Mention an important use of carbon dioxide.
7. What would happen if you poured a glassful of carbon dioxide gas into a glassful of air? Why?
8. When is air good, and when bad?
9. Illustrate and explain the proper method of breathing.
10. Mention several general properties of air.
11. Describe simple experiments to illustrate two properties of air.
12. What is a barometer?
13. Complete, orally, these statements:
    (a) Breathing is more difficult as we ascend to great heights, because—.
    (b) At sea level, the column of mercury in a barometer stands at about —— inches.
14. Name several toys which depend on properties of air.
15. Name several machines or appliances which make use of air pressure.
16. If you had a tank of carbon dioxide gas and a tank of oxygen, which should you draw on to put out a fire? Why?

Projects

1. Make a popgun out of the bark of a tree. Use it, and explain the action of the air in it.
2. Make a siphon. Use it, and explain its action.
3. Take apart a hand air pump. Show how it works to compress air. Make labeled drawings to illustrate its workings.

Outdoor Observation

1. Fly a kite and observe the effect of air upon it under different conditions.
2. In the course of a walk, list your observations and impressions of air as given you by your senses.

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CHAPTER V

WATER

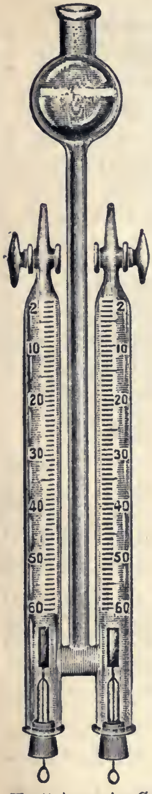
Water is one of the common things that daily show us the many ways in which matter can change its form. We see it flow quietly in a stream, or dash itself to spray and mist on the rocks under a waterfall. We see it float in clouds above us, glisten on the grass as dew, fall as rain, or hail, or in exquisite snow crystals. We see it freeze to a solid, or heat to steam and vanish from sight into the air. It influences our climate and affects our comfort and our health.

Water is everywhere. Not only does it cover three-fourths of the earth's surface, but it is in the air about us and in all living things. We ourselves are more than half water. Without water, life cannot continue. For our own good we must know something about water, about its service to us, and about the necessity of keeping pure the water that we use.

Water is a compound of two gases—hydrogen and oxygen. The gases unite in the ratio of two parts of hydrogen to one part of oxygen. Therefore water is known by the familiar chemical formula H_2O, in which H_2 stands for the two parts of hydrogen and O for the one part of oxygen. In a pure state, water, like its elements hydrogen and oxygen, is colorless, tasteless and odorless.

Experiment to Show the Composition of Water.—That water is made up of these two gases, hydrogen and oxygen, may be shown by the use of an instrument called an electrolysis apparatus. This consists of two connected glass tubes each containing a platinum plate known as a terminal, or electrode. Electrolysis is the act of breaking up a substance into its elements by means of electricity. To break up water into its elements, fill the electrolysis apparatus with water made slightly acid with sulphuric acid. Connect one wire of an electric storage battery circuit to one terminal of the apparatus and the other wire to the second terminal. If a storage battery is not at hand, two or three dry cells may be used. Bubbles will start to form on the

inside of each tube at the terminal, and will then rise in the tubes. It will be found that twice as much gas forms in one tube as in the other. These are the two gases of which water is composed, one of which scientists have proved to be oxygen and the other hydrogen. The larger amount of gas is hydrogen.



Knott Apparatus Co.

ELECTROLYSIS APPARATUS

An electric current breaks up the water into oxygen and hydrogen.

Distribution of Water.—Water is widely distributed. Of the 197,000,000 square miles that make up approximately the surface of the earth, about 144,000,000 square miles, or nearly three-fourths of the earth's area, are covered by the oceans, lakes, rivers and small streams of water. Water is a part of all living things and is necessary to their growth. Many inorganic materials absorb it, such as porous rock and sand.

The water on the earth is constantly evaporating, that is, changing into water vapor. In this form it rises into the atmosphere and forms clouds and mists. These finally condense into the rain which falls on the earth. This process is going on all the time and greatly influences the weather of every section.

Water and Heat.—It takes more heat to change a given amount of water one degree in temperature than any other of the common things we know. The rocks and soil require a much less amount of heat to change their temperature one degree than does the same weight of water.

Experiment to Show Change in the Temperature of Water.—Place a given amount of water, say one pound, in a tin dish. Warm this water to a rather high temperature but not to the boiling point. After taking the temperature of this hot water, add an equal amount of cold water whose temperature is known. The temperature of the mixture will be approximately the average, or half way between the two temperatures taken.

If, then, another pound of hot water, the same temperature as the first reading, be taken and a pound of small stones at the same temperature as the cold water be dropped into it, the temperature of the mixture of the stones and hot water will be changed only a little from that of the hot water. The heat used to warm the cold water in the first part of the experiment must have been taken from that of the hot water. The same is true of the stones, but it will be noticed that the hot water did not cool as much when the stones were placed in it. This shows that less heat was needed to warm the pound of stones than the pound of water.

Climatic Effects of Water.—Bodies of water are one of the principal modifiers of climate. Water both heats and cools slowly. It absorbs heat and then as gradually gives it off. During the hot months the oceans and lakes become storehouses of vast quantities of heat. Since water does not receive or give off heat readily, large bodies of water may be exposed for a long time to hot weather conditions without becoming very warm, or to cold weather conditions without becoming very cold. The temperature of the ocean varies only about 15° Fahrenheit during the whole year.

Land warms and cools more rapidly than water. Land becomes quite warm during the day while the sun shines and causes the temperature to become higher, but since land gives off its heat quickly, the temperature lowers rapidly at night. Hence, while water experiences only slight and gradual changes of temperature, land experiences great, and often sudden temperature changes. It follows that inhabitants of places located near large bodies of water enjoy a more uniform climate than those who live in places in the same latitude far inland.

Lake, river and sea breezes are likewise caused by the fact that land raises the temperature of the atmosphere above it by giving off heat, so that the warm air rises and cooler air rushes from the lake, river or sea to take its place, thus causing a sea breeze in the daytime. At night, when the land becomes cool and reaches a temperature below that of the water, the air cools, settles and flows out toward the warm water of the lake, river or

sea, causing a land breeze toward the lake or sea as the warmer air over the water rises.

Effect of Large Bodies of Water on Crops.—Because of their influence in modifying temperature, large bodies of water greatly affect growing vegetation and especially food crops. Vineyards are more profitable near a lake or other body of water because the heat carried by the winds from the water to the land keeps the section above the freezing point later in the season and thus allows the grapes to ripen. Further inland, where this heat fails to reach, frosts occur and destroy the grapes before they ripen. The same thing happens to other crops. In Labrador, the coasts are cold and have scanty vegetation, owing to the influence of the cold ocean current from the polar regions that flows near, while in Great Britain, in the same latitude, the coasts are warm and vegetation flourishes, owing to the nearness of the warm waters of the Gulf Stream that flows near its shores.

Uses of Water.—Water has many uses, chief among which is its aid in sustaining the life of all living things. For this it is a necessity. All other uses are slight in comparison. There never was a time when man did not recognize the necessity of having a supply of water that was fit for him to drink. In seeking for new places to dwell, man's first consideration has always been to find sufficient water for his family and his flocks.

Some of the most wonderful structures built by man have been for the purpose of providing water. The great Roman aqueducts and reservoirs—ruins of which may still be seen—show that people of past ages went to tremendous labor and expense to secure adequate water supply. In the western part of our country in modern times, immense dams have been built to hold water for the purpose of irrigating desert lands to make them productive for man and beast.

Water always has provided food for races of men that dwelt near lakes or streams or on ocean shores. In some cases, fish was the main article of diet. In the old days, when streams or lakes were fished out, those dependent upon them for their living were obliged to move to other localities. For the same

reason, until very recently, men fishing for sport frequently had to seek out new streams.

Today, science is changing this. By scientific methods of catching, curing, canning and shipping fish, the fish supply may be distributed throughout the world to points of need. Moreover, the fish supply in small and in large bodies of water is being safeguarded in various ways. Laws now limit the size of the catch and the times during which fish may be caught. Other laws, which prohibit the emptying of impurities into the waters, also help to protect fish. In addition, fish hatcheries have been established under state and under national control and are doing wonders in restoring the supply of fish. These institutions hatch fish by the millions and, by means of scientifically designed tank cars, distribute them over the entire country.

The uses of water for pleasure, for health and for recreation should not be overlooked. Boating, bathing and swimming all make for the health and strength of a people. Especially at or near large centers of population, provision for these sports means very much for community welfare.

Water will flow and under proper conditions will exert pressure. Upon these properties depends its immense value in industry and commerce. As it flows in streams, it affords opportunities for transporting material from place to place, making trade between these places possible. The ocean, also, has been for centuries a highway for trade.

The unevenness of the surface of a country is due largely to the action of running water. Water hollows out valleys and causes the irregular outline of highland and mountain ranges. Evidences of this wearing action may be observed in the garden or along the roadsides during and after hard rains.

Water is called the great *solvent* because of its power of dissolving so many materials with which it comes in contact—gaseous, liquid or solid. Flowing streams are continually bearing oceanward materials in solution. Consequently the oceans are great storehouses of matter deposited by streams and rivers.

Some Simple Experiments to Show the Properties of Water.—From the height of a few feet, pour water from a

pitcher onto the blades of a toy water wheel. The pressure of the falling water causes the wheel to revolve. Energy, that was potential in the water when it left the mouth of the pitcher, is released when the water strikes the wheel and exerts this pressure. In the same way, the water at the crest of Niagara Falls has po-

J. A. Glenn.

AUSABLE CHASM
The water has worn away the solid rock.

tential energy which is released as the water flows against the turbine wheels at the base of the falls.

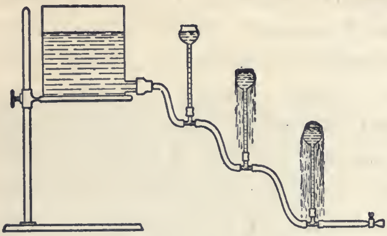
To show the dissolving property of water, stir salt in a glass of water. What happens? Boil the water until it evaporates, and the salt will be found to remain in the bottom of the dish. This illustrates the solvent power of water. Most water has substances in solution. It often has lime, which is sometimes seen deposited in the bottom of the family teakettle. Beautiful rock formations, resembling icicles, are sometimes found hanging from the roofs of caves. These were made by the evaporation of water holding lime in solution as it trickled from above.

To show that water quickly rises in porous substances, those full of small spaces, place one end of a strip of blotting paper in a dish of colored water. Observe what happens. This ability to fill the spaces in porous materials is known as *capillarity.* It accounts in part for the rise of sap in trees. It is also capillarity that makes it possible for us to dry our hands with a towel.

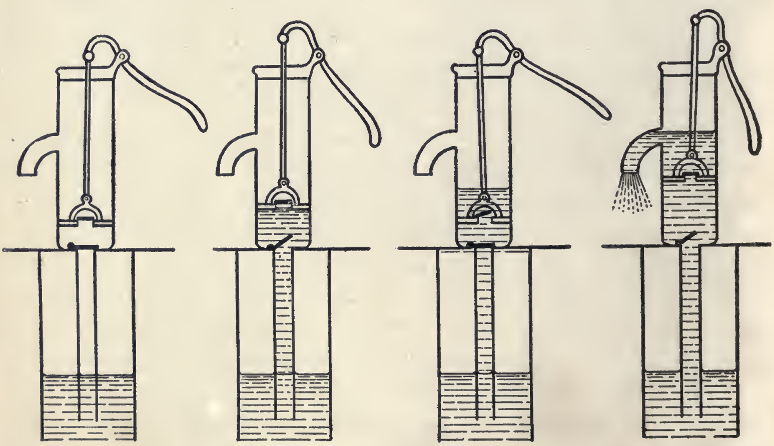
To show that water seeks its own level: Cut a hole in the side of a can near the bottom. Insert in the hole one end of a glass tube which is bent at right angles. Turn the other end upwards. To prevent leakage, seal the opening around the connection with wax. Fill the can with water. Observe how high water rises in the upright arm of the tube. This rising of the water in the tube is due to the downward pressure caused by the weight of the water in the can. Because of this tendency of water to rise to the level of its source, a water reservoir is placed higher than the homes it supplies. From it water flows down through underground mains and rises again in the house pipes.

The Home Water Supply.—The source of the water used in the home may be a well, a spring, a river or a lake. From whatever source it comes, great care should be taken to make sure that all water used for drinking is free from disease germs. This can be assured only by microscopic examination of the water by an expert. The clearest water may contain germs of some dangerous disease. On this account, it is vitally important that all water mains, pumps, pipes and faucets be kept free from organic matter and as clean as possible.

Experiment to Show the Principle of One Type of Water Supply System by a Model Apparatus.—Set on an iron ring stand a can having an outlet in one side near the bottom. Attach one end of a piece of rubber tubing several feet long to the outlet, allowing the tubing to extend gradually downward. Insert several thistle tubes at intervals in the upper side of the tubing at different heights from the floor. Then, from a jar below, pump water into the can. What becomes of the water after it reaches the can? What do each of the following represent in a water system: the can, the jar, the pump, the tubing, the thistle tubes?



EXPLAIN HOW THIS ILLUSTRATES A WATER SUPPLY SYSTEM



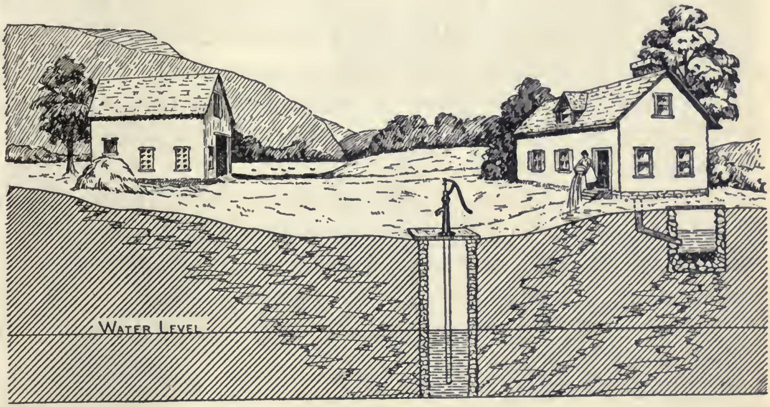
A LIFT PUMP

When the piston is drawn up it removes most of the air from the tube. Atmospheric pressure forces up water to replace the air. Succeeding strokes continue to raise the water past the two valves until it flows out of the spout.

Dangers From Faucet Filters.—A faucet is a device fitted with a valve in such a way as to control the outlet of a pipe carrying a liquid. A filter is a device used for straining any undesir-

able matter from a liquid. It may be made from porous brick or stone, or it may be a box partially filled with gravel, sand, charcoal, or other substance through which water will flow. The undesirable matter lodges in this substance, and the water comes from it more or less purified according to the efficiency of the filter.

A faucet filter is merely a small filter attached to a faucet. It may be made of a piece of porous rock, of baked clay enclosed in a metal tube, or merely of a piece of cloth placed over the mouth of the faucet. Such filters are sources of danger unless frequently cleaned to remove all collected matter in which disease germs may live or multiply. The best filters are not a sure



A Bad Place for a Well. Why?

protection against all disease germs, since most germs are so minute that they can pass through any filters with the water.

Method of Supply.—Although water in mountainous districts may be supplied by gravity, an abundant supply of water can usually be obtained only by the use of a pumping system to lift water to standpipes or reservoirs. Water flows from these into huge pipes, or water mains, which feed the smaller pipes running to houses. In country homes, water for household purposes is commonly lifted from wells by means of pumps.

Location of Wells.—Farm wells from which drinking water is drawn should not be located near the barnyard drains, cess-

pools or other places where organic wastes are liable to accumulate. This is especially important if the waste comes from the human body, since it may contain disease germs. Cases of typhoid fever are often traced to water taken from a well near which such waste is allowed to remain. Such material in water is called *pollution*. Since ordinary wells receive their supply from water purified by soaking or filtering for some distance through the ground, they should be so constructed that surface water cannot get into them directly.

Sanitary Control of Sources of Water.—Not only is it necessary to protect wells from pollution, but it is also necessary to protect all sources of water supply such as springs, rivers and lakes. If cities on river banks could prevent the disposal of sewage into the river by cities and other communities located farther up the stream or on the banks of its tributaries, there would not be the necessity for expensive water systems. Such sanitary control is very desirable.

It often happens that persons returning from a vacation spent at a summer resort or camp are taken ill with typhoid fever or some other ailment, the germs of which were acquired from the water in the places where they were staying. This danger can be avoided only by proper sanitary control of the sources of water supply.

City Water Supply.—In cities and towns of large size, the problem of securing an adequate supply of pure water is often a difficult one to solve. Although many cities are near rivers and lakes where there is plenty of water, it is often not fit to drink owing to sewage material which has been thrown into it. On this account it has become necessary either to bring water from great distances, or to install large water systems with settling tanks and sand filters to purify the water, and extensive pumping apparatus to force it to the places where it is to be used.

In order to get sufficient pure water for her millions of inhabitants, New York City bought a great area in the Catskill mountains and compelled the people living there to move away so that they could not pollute the water in the streams and reservoirs. This Catskill region is over 100 miles from New York City.

In reaching the city, the pure mountain water must travel many miles along a giant aqueduct, a tube for carrying water, and then must travel underneath the Hudson river in a great tunnel. This elaborate water system cost New York City many millions of dollars, but it is worth many times that amount to the city, for on it depends the health of the inhabitants. Other

International Newsreel.

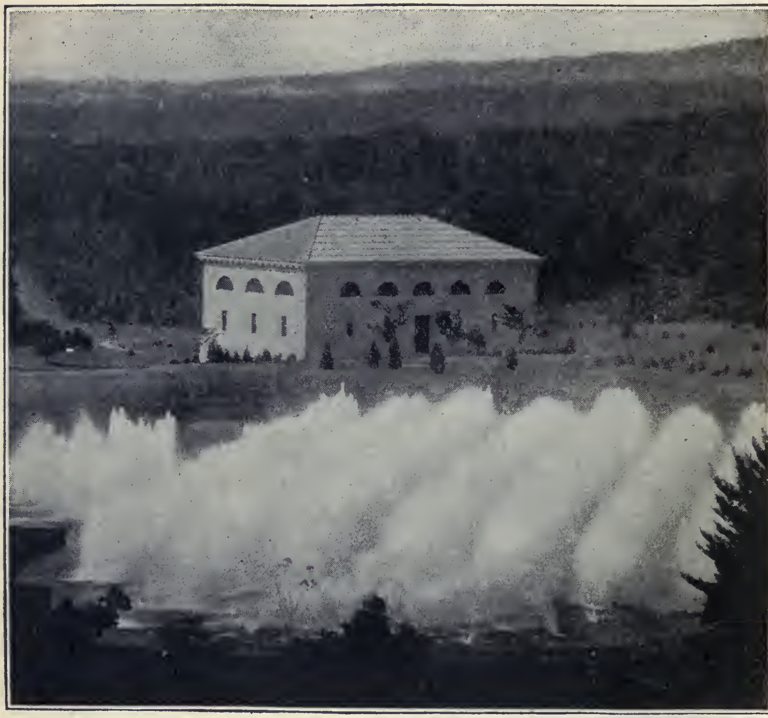
Overflow from Croton Reservoir
A part of the water supply system of New York City.

communities do not hesitate to spend enormous amounts for the same purpose.

In the water systems of some cities, the water is thrown high into the air as it is pumped or flows into the large reservoirs that hold it until it is used. As it falls back into the reservoir, the water

is broken up into small particles or drops. In this manner, the sunlight and air, which kill germs, come in contact with the water. This process is called *aeration.*

Some other cities treat their water with chlorine gas. Such a small amount of chlorine is used that one cannot even taste it in



Keystone View Co.

AERATION OF WATER

Spraying water into the air so that sunlight and fresh air will purify it.

the water, but it is sufficient to kill any germs that may be present. This process is called *chlorination.*

Mineral Springs.—A hole in the ground or a crevice in a rock, from which water flows naturally, is called a spring. The original source of spring water is rain on land higher than the springs. The water flows along beneath the soil until it comes to the surface at some lower point. When the land through which

the water flows contains any soluble mineral matter, the water often collects it and carries it along in solution. Such springs are called *mineral springs.* Water from some of these springs is used in great quantities as medicine. There are about 300 mineral springs in the United States where the water is sold in the belief that it promotes health.

The waters of mineral springs are classified according to the minerals dissolved in them. Among the well-known springs where these mineral waters are found are the hot springs of Virginia, the saline and the alkaline springs of Saratoga, New York, the white sulphur springs of Ohio and the alum springs of Virginia. The waters of some of these springs, as at Saratoga, also contain small amounts of iron, carbonate of lime and other substances with only a trace of organic matter. Thousands of people visit Saratoga each year for the purpose of drinking these health-giving waters.

Artesian Wells.—Artesian wells received their name from Artois, a province in France, where they were first developed. An *artesian* well is a well from the top of which water flows continuously. At times it even spouts many feet into the air. Such a well may occur in regions where underlying rock is in layers and where there is a porous layer between two solid layers. The water collects in and flows through the porous layer, held in by the hard layers.

If these layers of rock do not lie horizontally they will come to the surface somewhere. If this should be where the land is high, as in a mountain range, the rain from that point will fill the porous layer. The solid layers will confine this water to the porous layer and it may flow through the pores for many miles and often at great depths. If a hole is bored down to the porous rock at any point where the country is lower than where this layer receives the water, the water will flow out the top of the hole on account of the pressure caused by the weight of the water in the higher levels in this same porous rock.

Water that comes from these wells is usually of excellent quality, free from disease germs, and therefore desirable for drinking purposes. It nearly always contains mineral matter,

and is then called a mineral water. In a certain section in South Dakota there are many wells of this kind, from some of which the water spouts to great heights in large quantities. In the wells at Calais, France, the water comes through the rocks from a very distant source in England. In reaching Calais, it passes through porous rock layers under the English Channel.

Sewage Disposal.—The disposal of sewage is one of the most important problems of every community. The accumulation

Brown Brothers.

AN ARTESIAN WELL

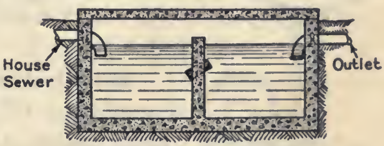
The pressure of water coming from a higher level and imprisoned between rock layers underground makes this well flow.

of human waste matter is one of the most serious dangers to health. The germs of typhoid fever, dysentery, and cholera, are given off in the waste from the bodies of people who have been ill with these diseases. If care is not taken in disposing of these body wastes, the germs may be carried by food or water to other people who in turn may spread the diseases. It is claimed that if all human wastes were properly disposed of,

these diseases would no longer prevail. Water is the means of carrying away this waste to places where it will become purified. The problem of proper sewage disposal is a most important one in both city and country districts.

Methods in Rural Districts.—In rural sections, until recent times, sewage from the farm house was piped a few feet from the house into a small walled place called a cesspool, or it was left exposed in a box-like receptacle in a small outhouse. In the case of the cesspool, which was usually not watertight, the liquid from the sewage soaked into the surrounding soil and polluted it, and this liquid, flowing through the ground, was liable to find its way into any near-by well. In the case of the outhouse, flies were constantly walking over the wastes and carrying small portions on their feet to any food that might happen to be unprotected near or in the house. In either case, it might happen that germs from the excreta of a person suffering with a communicable disease, such as typhoid fever, might be carried into the house, either by water or by flies, thus exposing healthy persons to the disease. Sometimes whole families became ill on account of these improper methods of waste disposal.

The Septic Tank.—Fortunately these poor methods of sewage disposal are being replaced to a greater or lesser extent by the use of the *septic tank*. This consists of an underground cement tank, usually having two or three sections, located 25 to 30 feet from the house. Into it, wastes are conveyed from the house by water in pipes.



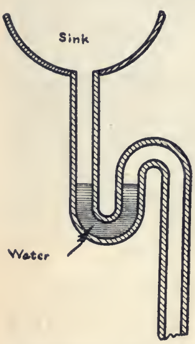
THE SEPTIC TANK
A guardian of health.

The more solid part of the sewage settles in the first section and is attacked by certain *bacteria,* or tiny forms of life, which feed on it, and cause it to decay and dissolve. This solution then passes through an opening into the second section where the work of the bacteria continues. This section serves as a storage place until the solution becomes quite clear and has lost most of its solid matter, when it passes into the third section, from which the liquid finally passes into the ground, where soil bacteria render the

remaining organic matter harmless. When the tank has only two sections the liquid is discharged into the soil from the second section. This method of sewage disposal requires a water reservoir in the attic or some elevated place into which water has been forced from a cistern or other source of supply by some kind of pumping apparatus.

Method in Urban Districts.—In large towns and cities, the sewage leaves the houses in pipes leading into larger underground pipes which conduct it to a still larger pipe from which it is finally discharged into some body of water, or into immense septic tanks similar in structure to the small septic tanks just described. In cities on the shores of the ocean or of large lakes, the largest pipe is sometimes extended quite a distance into the water, where the sewage is discharged and widely scattered by the tides and the currents.

Cities on the banks of rivers often discharge their sewage into the river water. Although this method may be inexpensive, it is clearly unfair to other cities farther down the stream which take their drinking water from that source. Wherever sewage is discharged into the water supply of a community, a disposal plant should be maintained. Not to do this is a menace to the health of that community.



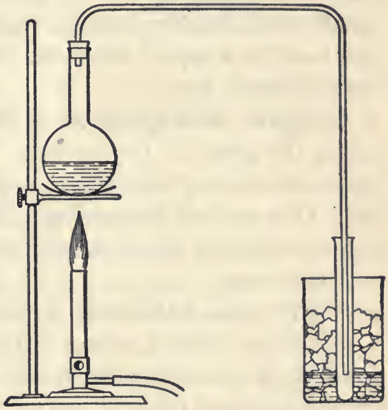
A WATER TRAP
This keeps out sewer gas.

House Plumbing.—Plumbing is the arrangement of pipes and other apparatus to carry water into, through, and out of a building. It is especially necessary as an aid in the disposal of sewage.

Drains are of the greatest importance from a sanitary point of view. They should be so constructed that no gases given off by waste matter can escape into the house; therefore they should be made entirely of metal and should be air-tight. Iron is commonly used for making the larger and longer pipes, and lead for the smaller and shorter ones. The main drain pipe should be ventilated and every opening should be protected by a trap. A trap consists of a bend, like the

letter S, in the drain pipe just after it leaves the sink. As long as the trap contains water, foul gases will not back up into the house, as sewer gas will not pass through water.

Distillation of Water.—Distillation is a process of purifying water by boiling it and collecting the steam which is afterwards condensed back to water by cooling. By this means, all undesirable solid matter in the water is left behind. Gaseous impurities, however, often pass off with the steam.



DISTILLING WATER

To distill water: Fill a flask about one-half full of water and insert in the opening of the flask a rubber stopper. Through this pass one arm of a bent glass tube. The other arm of the tube should reach into a test tube set in a beaker of ice or snow. Heat the water until it boils. As it boils, the vapor arising from it passes from the flask into the test tube where it is at once condensed into water by coming in contact with the cold surface of the test tube. All solids which were dissolved in the water will be left in the flask. The distilled water in the test tube will be clear, odorless and tasteless.

Ice Manufacture.—The demands for ice for preserving food in homes and storage plants, for cooling drinks and for making ice cream have enormously increased in recent years. Ice is required in all seasons, and often at points far from the sources of supply—the frozen lakes and streams of the north.

The uncertainty of this supply, the cost of harvesting and shipping, the tremendous loss through melting, and the dangers of impurities in natural surface ice have led to the development of great plants to manufacture artificial ice from pure water. Such plants are now the main source of the ice dealers' supply.

Manufactured, or artificial, ice is made in ice plants by the evaporation of ammonia or sulphur dioxide gas which has been

made a liquid by means of great pressure. This liquid is forced into pipes running through a tank of brine—water full of dissolved salt—and there it turns back to gas. This change of a liquid to a gas requires heat, which is taken from the brine. In this brine are suspended containers full of pure water. As the temperature decreases, the pure water and the brine become equally cold, but the brine having the lower freezing point of the two remains a liquid while the pure water changes to pure, clear, manufactured ice.

Electric Refrigeration.—The electric refrigerator is today taking the place of the ice box. Its motor condenses a gas to a liquid which later expands to a gas in pipes within the refrigerator. This process absorbs heat and produces a low temperature. At the same time ice for family use is made in partitioned drawers near the pipes.

Water as a Cleansing Agent.—The best water for cleaning is soft water, that is, water without any mineral matter in solution. Rain water is soft water. Water from wells and springs usually contains mineral matter in solution taken from the soil. Such water is called hard water. It does not readily combine with soap and so is not as efficient for cleaning.

Experiment to Show How Hard Water May Be Softened by Means of Washing Soda, Borax, Etc.—Put a half pint of hard water in a beaker and stir in it a tablespoonful of borax or washing soda. Allow the solution to settle and pour the clear part into a bottle. Add a little soap and shake. In a second bottle add soap to hard water and shake. Compare what occurs in the two bottles and account for the different actions.

Cleansing Agents Used with Water.—Effective as water is in cleansing, it can be made even more effective by the use of certain materials. Among these are soaps and alkalis.

Soap.—Soap is a substance extensively used with water in cleaning. Its great value lies in the fact that it will form an emulsion with grease or oil; that is, it will break up the grease or oil into small particles so that it becomes easy to remove it by the application of soft water. Perhaps you have noticed how difficult it is to remove grease from a piece of cloth by merely rubbing it

in water, but how readily the grease comes out of the cloth if you first rub it with soap and then rinse it in water. Soap is necessary to cleanliness. It is made of fat and of a product called *lye* obtained by treating wood ashes with water and lime.

The preparation of soap may be shown in the following manner: Fill a beaker one-third full of water and one-third full of a mixture of lard and lye, in the proportion of three parts of lard to one part of lye. ***Caution:*** *Do not allow the lye to touch the hands or clothes.* Boil the mixture for 45 minutes; then pour it into a pan and let it cool and set for several hours.

Formerly it was customary to use the hands in washing soiled clothing. It required hard rubbing to make the soap and water combine with the greasy dirt in the clothes. Now laundry machinery is used to do this work. The clothes are placed in a box-like enclosure having an apparatus capable of whirling them in a soap and water solution. This apparatus is run by the use of electricity or steam, thus relieving the housekeeper of much hard work.

Alkalis and Acids.—An *alkali* is one of a class of substances widely used in cleansing, and in counteracting the effect of *acid.* Alkalis are soluble in water or alcohol and, when combined with fats or oils, make soap. Baking soda, caustic potash or lye, and household ammonia are common alkalis. The presence of an alkali may be shown by the use of litmus paper. An alkali turns red litmus paper blue.

Acids may be recognized by their sour taste, and by the fact that they turn blue litmus paper red. Unless immediately counteracted by an alkali, most acids will eat holes in materials upon which they are spilled.

When an acid and an alkali are combined in proper proportion a *salt* is formed. This process is called *neutralization.* While strong acids and alkalis may injure objects with which they come in contact, salts are harmless. For example, when sulphuric acid from a radio battery has been spilled on clothes, the immediate application of an alkali such as household ammonia will form a harmless salt and save the clothes.

Tooth Pastes and Powders.—The value of tooth pastes and tooth powders, which are so extensively used, lies in the fact that they contain alkaline substances which counteract the bad effect of the acid substances that form in the mouth and attack the teeth. Care should be taken not to use tooth powders too freely since they sometimes contain material which will injure the teeth.

Tooth paste contains a soap to aid in the cleaning of the teeth, some substance such as milk of magnesia for neutralizing the acids in the mouth, often something that will destroy any germ life that may exist in the mouth, and some flavoring such as peppermint or wintergreen.

SUMMARY

Water is a colorless, odorless and tasteless compound of two gases—oxygen and hydrogen.

Water is widely distributed on the surface of the earth, covering nearly three-fourths of its area.

Bodies of water are among the greatest modifiers of climate.

Large bodies of water, by making the climate milder, help the growth of crops that are raised near their shores.

Water has many uses, the most important of which is its aid in sustaining the life of all living things. It gives us our fish supply and affords healthful recreation.

Water will flow and exert pressure. Upon these properties depends much of its value to man.

Sources of home water supply are wells, rivers and lakes, from which water is often obtained by pumping.

Sanitary control of the sources of water supply is most essential. Every possible effort should be made to prevent pollution of water intended for drinking.

Water is an essential agent in the disposal of sewage.

Proper plumbing is necessary to keep sewer gas from entering houses.

Water is a great solvent.

The manufacture of artificial ice from water is an important industry.

Soap is a substance used with water in cleaning. It is especially valuable for this purpose, since it will form an emulsion with grease or oil.

Alkalis are certain substances used in cleansing materials, and in counteracting the effects of acids. When acids and alkalis are combined they form harmless salts.

Fact and Thought Questions

1. Complete orally the following statements:
   (a) Water is composed of the gases ——.
   (b) Water covers —— of the earth's surface.
   (c) Three common sources of water supply are ——.
2. What becomes of water that falls to the earth in a storm?
3. How do large bodies of water affect land crops?
4. Name several conditions which make water unsafe for drinking.
5. There are excellent springs at about equal distances above and below a hillside farmhouse. From which spring would you advise drawing the house water supply? Why?
6. Would you expect to find a spring on the summit of the highest land in your neighborhood? Why?
7. Mention ways of sewage disposal in which water is employed.
8. Why is the septic tank more sanitary than the cesspool?
9. Why is good plumbing necessary to a home?
10. Suggest three ways in which the power of water to dissolve material helps us.
11. Where does your town, or the nearest town, get its water supply?
12. Why is a water tank often placed higher than the building it serves?
13. Name certain steps that should be taken to safeguard a water supply from pollution.
14. How is artificial ice manufactured? Is such ice different from natural ice?
15. Describe three ways in which water is purified.
16. Define (a) soap, (b) emulsion, (c) acid, (d) alkali, (e) salts.
17. How does soap act as a cleanser?
18. Define hard water. Define soft water.
19. Would you rather wash clothes in hard or in soft water? Why?
20. What causes mineral springs? Are all mineral springs valuable for drinking purposes?

Projects

1. Describe the water supply system of your town.
2. Make a small jar of soap. Tell briefly how you did it.

3. Study and report on the devices used to distribute and regulate the supply of water in your home.
4. Carry out a series of experiments to show the great solvent power of water.
5. Make a labeled drawing of a septic tank.

Outdoor Observation

1. Observe and list the visible effects of a heavy rain on soil and plant life.
2. Observe and record effects of frost.

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.... *Farmers' Bulletin 478, U. S. Dept. of Agriculture*
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CHAPTER VI

WATER POWER

Through the ages, water has served man in many ways. Ocean and lake have supplied fish to feed him. Stored and then carried long distances by man's ingenuity, water has transformed deserts into wonderlands of growing crops. Up and down rivers and across the oceans have gone great ships to gather and distribute the food and other materials that man needs.

But there is one great use of water that man was slow to profit by. For ages the streams of the world have gone roaring and swirling down to the sea unhindered, and power equal to that of countless millions of horses has been wasted. Now, however, man is seeing in the whirling, tossing rapids and waterfalls, not only beauties of nature, but also the white coal of the future that will largely take the place of our diminishing coal beds.

In the streams of this country alone is unused power sufficient to drive, twice over, all our factories and transportation systems. And along the seacoasts where tides are high, as in the Bay of Fundy, men are taking the first steps to harness the limitless power of the ocean. Science is making all this possible.

Water, fuel and wind provide much of the energy used by man in carrying on the activities of modern life. The energy of falling water is transformed into the energy of motion by revolving water wheels, and this energy in turn is passed on in other forms, such as light or electricity. The energy of fuel is released by oxidation and is quickly transformed into the energy of light and heat. The energy of wind is likewise changed into the energy of motion, as seen in the movements of windmills. This energy, in turn, may be changed into other forms. Of all these sources of energy which drive the great power plants that make our numerous industries possible, water stands next to fuel in importance.

Water turns to vapor because of the heat energy that comes to it from the sun. This energy causes the water molecules to separate and thus to form a vapor. This vapor rises into the atmosphere and, if dense enough, forms clouds. When these are further condensed water falls as rain. Some of it falls on hillsides and higher levels and finds its way into streams. As it flows down the hillside or leaps over the cliffs, the water is giving off some of the energy that the sun stored in it in vaporizing it and lifting it to the clouds. If, instead of flowing freely in its fall to lower levels, it is made to exert pressure on a water wheel, some of the energy is transformed and made available for the use of man.

In this country, and throughout the world, only an exceedingly small part of the available energy of water power in streams has yet been utilized. Only a small fraction of the energy stored in the falls and rapids of Niagara is turned to useful purposes. Engineers are now at work on plans to utilize some of the power stored in the great tides of the North Atlantic. There is more than enough of such power for all industrial needs. Moreover, scientists and engineers are constantly improving methods of conveying electricity long distances. Consequently, by changing water power to electric energy, it is possible to transport it to the points where it is needed. Water power is undoubtedly the great power of the immediate future.

Water Power in the United States.—New England, New York, Pennsylvania, Michigan, Wisconsin, Minnesota, Iowa, and some states farther west have developed large amounts of water power, but there is much more available even in these sections. The largest power plants in the country are at Niagara Falls, New York; Keokuk, Iowa; and Big Creek, California. The plant at Muscle Shoals, in Alabama, when fully developed, will probably be greater than these. The desirability of developing water power is apparent when the fact is known that it costs on the average only about one-half as much to generate power by water as it does by the burning of coal.

Much of the work that water is able to perform for us is due to the pressure it exerts. The experiments which follow will show the existence of this pressure and in what ways it is exerted.

Wide World Photo.

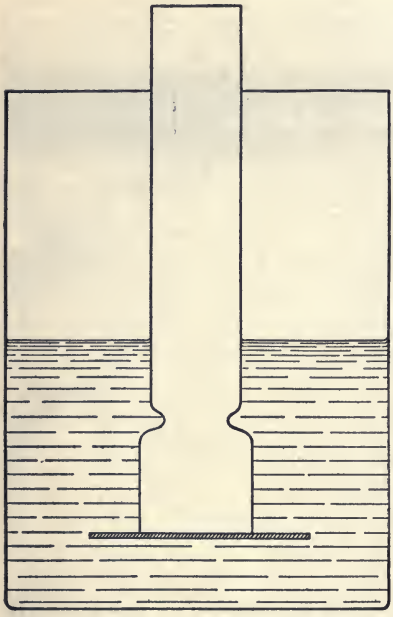
THE MUSCLE SHOALS DAM

When fully developed the Muscle Shoals power plant will be one of the greatest in the United States.

Experiments to Show Water Pressure.—Place a thin piece of cardboard about three inches square over the bottom of a common lamp chimney. Holding it firmly in place with the hand, lower the chimney about one-fourth its length into a dish of water. Then remove the hand from the cardboard. The upward pressure of the water will hold the cardboard in place. Gradually pour water into the chimney. When the level of the water in

the chimney equals that in the jar the piece of cardboard will no longer keep its place. Can you tell why?

To show that water exerts pressure upon surfaces and that this pressure can be measured and increased, perform the following experiment:



An Experiment to Show Water Pressure

Cover the large end of a thistle tube with a piece of very thin rubber sheeting. Fasten this tube to the lower end of a standard so that the rubber sheeting may face upward, downward or sidewise. To the other end of the thistle tube fasten, by means of rubber tubing, one end of a U-tube containing colored water or mercury. With the rubber sheeting faced upward, allow the thistle tube to sink in water and notice how the level of the liquid in the U-tube changes. Can you explain this? Notice how the amount of change differs as the thistle tube sinks lower.

Try the same experiment with the rubber sheeting on the thistle tube facing downward, and then sidewise. Compare the pressures as shown by the liquid in the U-tube for each of the positions of the thistle tube. The pressures indicated on the rubber sheeting are equal to the pressures on anything located at the same depth as the sheeting. These experiments may be performed equally well with three different thistle tubes.

The relation between depth and pressure may be shown by the use of a can having three or more holes in its side equally spaced from top to bottom. Plug the holes and fill the can with water.

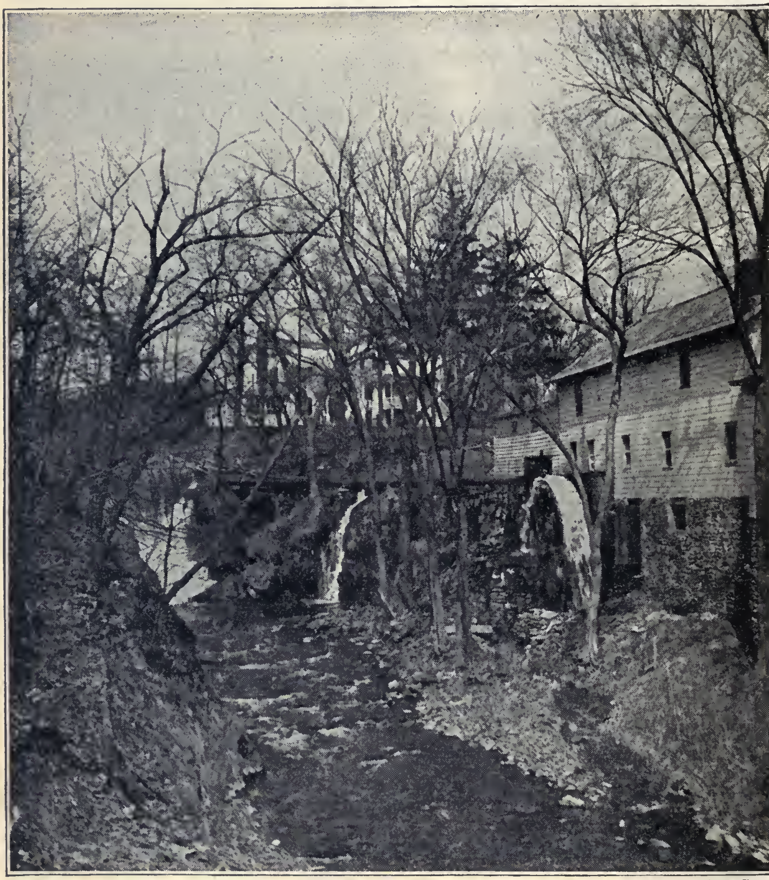
Then remove the plugs and compare the force with which the water runs out of the lowest hole with that of the water running out of the others. What does this indicate? Adjust a rubber inlet tube so that as much water flows into the can as flows out through the holes. In this way the level of the water in the can always stays the same. Catch in separate cups the water from two or three of the holes. The quantities of water caught will give an approximate measure of the pressures exerted. It will be found that if the depth below the surface is three times as great at one opening as at another, the pressure is three times as great at that opening as at the other, and if the depth is four times as great, the pressure is four times as great.

An Apparatus to Show Water Pressure

Water Wheels.—The history of the development of industry in all countries shows that running and falling water have long been used to provide power and to do work for the benefit of man. Various forms of wheels have been invented to utilize the force exerted by water. These wheels, in turn, drive machinery used for many purposes.

The efficiency of a water wheel depends not alone on the volume of water which flows against it, but also on the height from

which the water falls. A small stream falling from a great height may accomplish more work than a larger stream falling from a lesser height. This fact is of extreme importance in the practical use of water power.



Keystone View Co.

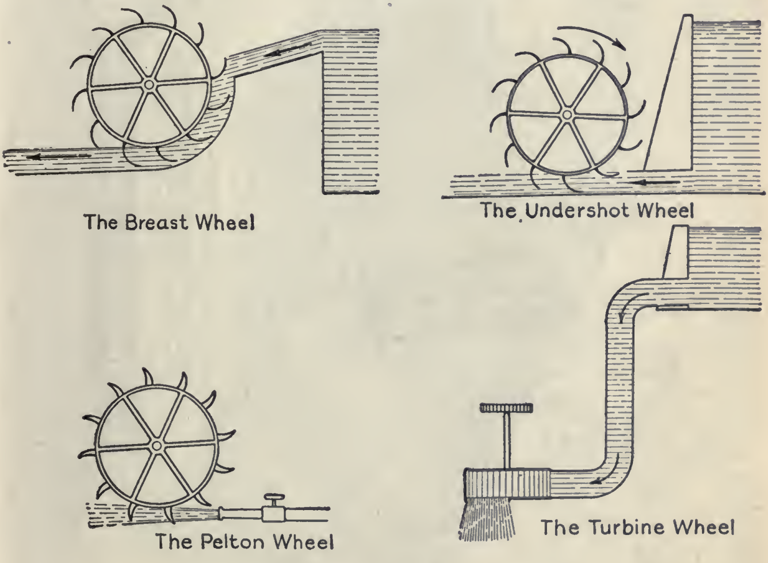
A PICTURESQUE OLD MILL WHEEL

The water which drives this overshot wheel is piped from the reservoir back of the waterfall.

Types of Water Wheels.—There are several kinds of water wheels, known as *overshot, breast, undershot, turbine,* and

Pelton wheels. The overshot wheel was extensively used in early times to provide energy for operating mills. It was sometimes of enormous size and was made with large pockets on the rim. These pockets were placed so that the water released from a dam above flowed on top of the wheel and into the pockets until their weight was sufficient to turn the wheel.

The breast wheel is quite similar in construction to the overshot wheel and is commonly used where there is a large supply of water falling a short distance. This wheel also has pockets on the rim. The water flows into the pockets at a point about

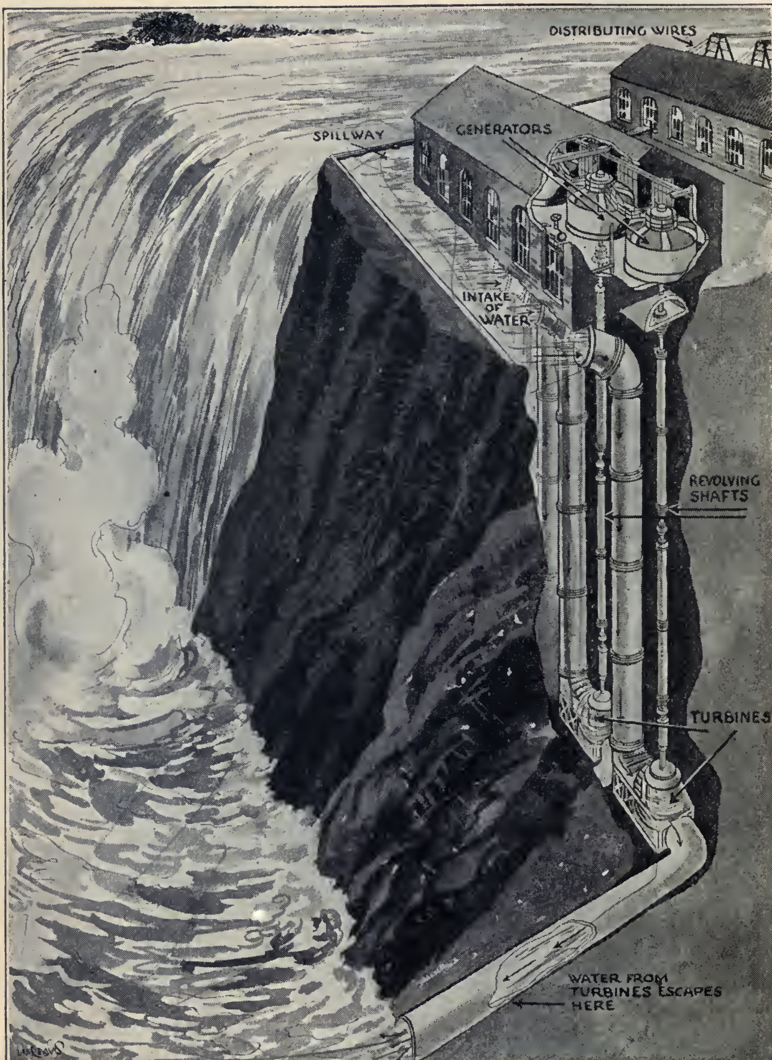


TYPES OF WATER WHEELS

level with the axis of the wheel. The weight of the water causes the wheel to revolve, as in the case of the overshot wheel.

The undershot wheel is used where the fall of water is slight. It depends on the force imparted by water flowing against its blades from underneath, as in a swiftly running stream.

Turbine Wheels.—The wheels described above have been largely replaced by the turbine wheel. This type of wheel can be well adapted to almost any condition of water supply. It



Popular Science Monthly.

A TRANSFORMATION OF ENERGY

The energy of falling water is transformed by means of turbines and generators into electrical energy.

may be designed for a slight flow or for a heavy volume of water, and for any amount of fall, or head. It acts on the same principle as the undershot wheel, except that it is placed horizontally at the base of a pit, and water is conducted to it through a pipe called a penstock. The water falling from the pipe strikes the wheel blades at right angles to the wheel axis, exerting great pressure, and escapes through an outlet as the wheel revolves. Its energy is transformed into the motion energy of the wheel, which revolves with great rapidity. The efficiency of the water power plants at Niagara Falls and Keokuk is largely due to the use of these turbines.

The Pelton Wheel.—The Pelton wheel is a modern invention adapted to great pressure but only to a limited amount of water. On its rim are a large number of cup-shaped buckets. The water is forced through nozzles under tremendous pressure, and as it strikes the buckets of the wheel nearly all of its energy is transferred to the wheel. It is used extensively in California and other western states.

Measurement of Power.—Energy, as we have said, is the ability to do work. It is measured in *foot pounds.* A foot pound represents the amount of work required to lift a weight of one pound a distance of one foot. The rate at which work is done is called *power.* This power may be measured in terms of *horsepower.* One horsepower represents 33,000 foot pounds per minute. All water power is measured in terms of horsepower.

The origin of the term horsepower is interesting. In the latter part of the eighteenth century, James Watt, the inventor of the steam engine, in trying to sell his engines to coal operators, found that the horse was a rival of his business. He determined to prove that his engine could do more work in the same amount of time than a horse could. So he set out to show what a horsepower represents in foot pounds per minute. He did this by a series of experiments with horses at work, and found that the distance in feet traveled by a horse in pulling coal and water up from a mine, multiplied by the weight lifted, averaged 33,000 foot pounds of work in one minute. This has been accepted as representing one horsepower.

Dams.—A dam is a structure built to stop or check the flow of water in a stream. In this way water is stored to provide a supply for homes or for communities; to irrigate, or water, tracts of land; to raise the level of streams in order to increase their depth for navigation purposes; to hold flood water of streams so as to reduce the danger of serious floods; or to supply power to run machinery. In the latter case much of this power is transformed into electricity in order that it may be distributed over great distances to the points where it is needed.

The United States Reclamation Service has constructed wonderful dams for the storage of water to be used in industrial pursuits, especially in agriculture. Among these dams is the Arrowrock dam in Idaho. This has a height of 349 feet, a length of 1,100 feet and a capacity of 91,238,000,000 gallons. The water from this dam will render productive about 234,000 acres of desert land.

The Roosevelt dam in Arizona is 280 feet high and 1,125 feet long. It is so placed that it backs up the water to form an artificial lake having an area of over 25 square miles and containing over 513,000,000,000 gallons. Such dams are usually placed at points where advantage can be taken of the general slopes of the ground to form reservoirs of considerable area and of great depth.

Although irrigation has been understood for many centuries, it is only beginning to be developed on any extensive scale. It is estimated that there are still ten million acres of land in our western states which could be made of value for crop growing purposes by irrigation.

In a message to Congress, Theodore Roosevelt declared: "The reclamation and settlement of the arid lands will enrich every portion of our country, just as the settlement of the Ohio and Mississippi valleys brought prosperity to the Atlantic states." Each year the Reclamation Service of the United States undertakes new projects calculated to conserve the water resources of the country. No country that fails to do this can hope for continuous prosperity.

SUMMARY

Water exerts pressure in all directions and this pressure can be measured.

Water, fuel and wind provide most of the energy used by man in carrying on the activities of modern life.

There exists in the United States a vast amount of undeveloped water power.

The principal kinds of water wheels are the over-shot, the breast, the under-shot, the turbine and the Pelton.

The turbine wheel is well adapted for use under a great variety of conditions.

The Pelton wheel is well adapted for use where there is a limited amount of water having a high fall.

A foot pound is the amount of work required to lift one pound a distance of one foot.

Energy is measured in terms of foot pounds of work.

Power is the rate of doing work.

A horsepower is a unit of measure of power and is equivalent to 33,000 foot pounds of work per minute.

Dams of great size are constructed for the conservation of water, for power, for irrigation and for other uses.

Fact and Thought Questions

1. How can water pressure be measured?
2. What forces provide most of the energy used by man?
3. Under what conditions will a small stream provide considerable power?
4. Will a stream supply more power by dropping to a fixed lower level in one fall, or by gaining that level in a series of rapids?
5. What is a dam? Describe one you have seen. For what purpose was it built?
6. Why are dams thicker at the base than at the top?
7. How may the opening of a water faucet downstairs affect the water flow from an upstairs faucet? Why?
8. Describe the effect of (a) drought and (b) freezing on water power.
9. Mention various kinds of wheels that utilize the energy of falling water.
10. Describe the turbine. To what conditions is it well adapted?
11. Describe the Pelton wheel. How is water applied to it?
12. Define: (a) foot pound; (b) horsepower.

13. Is more work done in lifting a 200 lb. weight 70 ft. in one minute than in lifting a 50 lb. weight 280 ft. in the same time?
14. Compare the work done in lifting 2,000 lb. a distance of 5 ft. in one minute with that done in lifting the same weight the same distance in four minutes.
15. Explain the principle on which this statement is based: Water seeks its own level.

Projects

1. Construct a small water wheel.
2. Make a labeled map showing the rivers in your state that produce, or might produce, water power.

Outdoor Observation

1. Observe and report on effects of ice on streams and pools.
2. Visit, observe and report on the nearest water supply system.
3. Follow up the nearest very small stream from mouth to source. Report on how it is fed, how it drains land, and how its banks have been affected by the flowing water.

References

The Story of Agriculture in the United States.................. *Sanford*
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GENERAL THOUGHT QUESTIONS FOR DISCUSSION AND REVIEW

GROUP I

1. Why does a basketball bounce when dropped on the floor?
2. What would happen to a bar of iron if placed in pure oxygen?
3. Are the greater number of springs on a hill likely to be situated near the base or near the summit? Why?
4. Does an inflated football weigh more than an uninflated one?
5. Is it true or false that pure and clear water can vaporize from a muddy pond? Why?
6. Why does vapor from a locomotive whistle promptly disappear from sight?
7. How would our lives be materially affected if energy could not change its form?
8. Complete these statements orally:
   (a) —— makes the mercury column of a barometer change its level.
   (b) Oxygen forms approximately —— per cent of the atmosphere.
   (c) —— is used to test for the presence of carbon dioxide.
9. Why does water run down hill?
10. Why is it difficult to dive into water to any great depth?
11. Suggest four ways in which environment controls our lives.
12. Name several ways in which we control our environment.
13. Why are lifeboats sometimes equipped with distilling apparatus?
14. Why does turning on a hot water tap in the kitchen on a cold morning cause a mist to form on the window?
15. Why is it advisable to know what has caused a spot on clothing before attempting to remove it?
16. Is there any water power in a still pond?
17. Is it accurate to state that dew "falls"?
18. Why doesn't air disappear into the space beyond the atmosphere?
19. Suggest an experiment to determine the amount of water in snow.
20. Under what circumstances is it possible to carry around an open pailful of gas?
21. What has water to do with the odd formations in limestone caves?
22. How is the sun's energy changed to water power?
23. Would a rubber ball bounce as well if the inside air pressure were the same as that of the atmosphere?
24. Why is the rain which comes from the ocean not salty?
25. Complete this statement orally:
    Two special properties of good shoe leather are ——.
26. Name some advantages of labeling materials and supplies.

27. Name three materials so alike that labels are advisable for quick identification.
28. What property of hydrogen makes it good for use in airships, and what property makes it bad?
29. Suggest several ways in which the solvent power of water is of value to us.
30. Is it true or false that the mercury column of a barometer rises as a storm approaches? Why?
31. Why is scientific progress more rapid now than a century ago?
32. Explain:
    Soft water requires less soap to make a lather than hard water.
33. Suggest an original experiment to show that matter occupies space.
34. Is it true or false that much-used stone stairs wear down by chemical change? Why?
35. Suggest several reasons why early settlers made their homes beside water.
36. Is it as necessary to-day to live near water as it used to be? Why?
37. Was it safer for the early settler to drink from running streams than it is for us to do so? Why?
38. Is it true or false that your arm has both potential and kinetic energy?
39. Is it true or false that cold days are better drying days than warm ones? Why?
40. Why do air cushions and air-filled tires lessen shocks?
41. Why is it wise to lower a lighted candle or a lantern into a vault before descending into it?
42. Name six basic elements of matter.
43. If an uncorked bottle of water is inverted, why does not the liquid flow out smoothly?
44. Why is a labeled diagram better than an unlabeled one?
45. Is it true or false that water taken from wells is often hard? Why?
46. Is it true or false that burning produces water? Why?
47. Two of the following devices depend on the atmosphere for their action: air gun, automobile tire, lift (suction) pump, sand blast, medicine dropper.
    a. Select one of these two devices and describe an experiment illustrating how it works.
    b. Make a labeled drawing of the device selected.

CHAPTER VII

HEAT

When man discovered fire his civilization began. Until then he had lived near drinking water, had eaten what wild fruits and roots appealed to his taste, and had devoured raw such fish and flesh as he could catch. For shelter he had depended on caves, and for warmth on the sun. He was bound fast to places where he could get these things.

His discovery of fire, perhaps from a volcano or from lightning striking a tree, opened a new world to him. He cooked his food and made it taste better. He heated his shelter, driving out winter cold. He baked clay for utensils and, by burning, hollowed out a log for a canoe.

In time, he discovered that heat would melt certain rock-like substances and give him metals. From metal he made tools with which to cultivate the soil, weapons for hunting and defense, and machines to do work. Gradually he made clothing, and better shelters, and, later, vessels that would move regardless of wind. And then, when from iron he made steel, the modern machine age began.

Fire and heat, then, play a tremendous part in our lives. They are wonderful as servants, but terrible in destructive power when out of control. That we have them is due to the sun, for it is the sun which, through the ages, has been providing the energy found stored in coal, oil, natural gas, and the wood of the forests.

Heat is another form of energy. We have learned that the sun is the source of all energy; therefore heat produced by burning wood or coal came originally from the sun. This energy was stored in the coal and the wood when they were in the form of growing plants. Again, if we rub our hands together, or rub the hand against a table top, heat is produced. This heat energy came from the sun to our food and from the food to our muscles. Our muscles change this energy to the energy of motion and this causes the friction which produces the heat.

We have prepared hydrogen gas by pouring hydrochloric acid on pieces of zinc in a bottle. As the acid acted on the zinc perhaps we noticed that the bottle became warm. This heat came as the result of chemical action. An automobile tire, when blown up hard, becomes a little warmer during the process. The adding of more air to the inside of the tire increases the pressure of the air, and this pressure produces heat. We turn on the electric light and notice that the bulb becomes warm in a very short time. We say that electricity produces heat. In sawing a piece of lumber we notice that the saw becomes hot from the friction. All of these different means of producing heat illustrate the transformation of energy.

According to the molecular theory of matter, all substances are made up of very small particles called molecules. These molecules are all in rapid vibration, even in heavy solids, like iron. The rate of motion of these molecules varies according to the heat of the body. As a body becomes warm it expands. This is caused by the molecules moving more rapidly and pushing each other farther apart, thus increasing the size of the body. As the body cools, the motion of these same molecules grows less, they draw closer together and the body shrinks in size.

When the builder places large rivets in a bridge to hold the iron girders together, he uses them red hot so that when they cool they will be shorter and so draw the parts more closely together. When a wagon maker puts a steel tire on a wheel, he makes it just large enough to go on the wheel when the tire is hot, and when it cools it shrinks and grips the wheel very tightly.

Were you ever traveling by rail when your train was forced to stop because of a "hot box"? This means that the axle was rubbing harder than usual on the part with which it comes in contact, called the journal box. Such friction produces heat. The journal box is filled with a cotton material, called waste, to hold a supply of oil, as oil reduces friction by making the parts move easily. If the oil supply becomes low the waste sometimes takes fire when the journal box gets hot.

These examples illustrate the transformation of energy. In each case the energy of motion is changed into heat energy.

In early times heat was called "caloric" and was regarded as a fluid. No one knew just what caloric was, but it formed a hypothesis to explain a change in temperature. Scientists believed that when caloric flowed into a body it became warmer, although it did not gain in weight, and when it flowed out the body became cooler. This hypothesis—that heat is a fluid—has been replaced by the theory that heat is energy resulting from the motion of molecules.

The sun gives off an enormous amount of heat of which the earth receives about one two-billionth part. Scientists have discovered that the exterior of the sun is made up of extremely hot gases, and they believe that in its interior these gases are very highly condensed. They are, however, unable to account for the origin of this heat.

Fire.—Everyone knows that fire will produce heat. No one knows when fire was discovered. The Indians produced it just as the boy scouts do today, by rubbing together two sticks of dry wood, thus raising the temperature of the wood to the temperature at which it takes fire. Our forefathers produced fire by striking a piece of flint with steel and then causing light substances to catch the spark and burst into flame. When the oxygen of the air unites with substances it causes oxidation, or burning. This oxidation is sometimes very slow, as in the rusting of iron. If, however, the oxidation is rapid enough to give off heat and light, as when paper burns, it is known as combustion.

It is less than one hundred years ago that the friction match was invented. This method of starting a fire was an advance over the use of flint and steel. A short, slender piece of pine wood was dipped in oil and then covered on one end with a mixture of sulphur, phosphorus and glue. When this end was scratched on a piece of sandpaper or on some other rough object, the friction caused sufficient heat to make the phosphorus ignite. The phosphorus, as it burned, set fire to the sulphur and then to the oily wood part of the match. It then was very easy to start a fire in other material by applying the burning match.

The sulphur match has been largely replaced by the safety match. The head of this match is usually coated with a mixture of sulphur, chlorate of potassium, powdered glass and glue, but no phosphorus. A mixture of red phosphorus, less active than yellow phosphorus, glue and other substances is placed on the surface where the match is to be scratched. Safety matches cannot be lighted except on this surface or on glass.

It is a long way from the method of primitive people in making fire by rubbing together two sticks to the modern method with the safety match, but friction is employed in both cases. Here is another illustration of the transformation of energy. Again energy of motion is changed into heat energy.

Experiment to Show the Necessity of Air (Oxygen), Heat, and a Combustible Substance to Start Combustion.—Place a candle in a jar of air. Touch the wick of the candle with small splints. Do they burn? Light the candle and place the splints in the flame. Do they burn? Cover the jar for a while. Does the candle continue to burn? If not, why? What do you conclude?

Kindling Temperature.—In order to make a fire, a certain degree of heat or temperature must be present. The kindling temperature is the temperature at which a substance will take fire. It varies much with different substances.

Place a quart of water over a Bunsen burner and note how long it takes for the water to boil; then in the same manner determine how long it takes to boil a gallon of water over the same burner. We find that the quart of water boils in a much shorter time. Both amounts of water have the same temperature, but the gallon of water contains four times as much heat. The temperature of a body, therefore, has a far different meaning than the amount of heat in a body.

The most common combustible products are wood, coal, charcoal, coke, oil, and gas. There are substances that will not burn in ordinary air. Among these are iron, stone, and asbestos. It is believed, however, that there is no substance that will not burn if the degree of heat is sufficiently high.

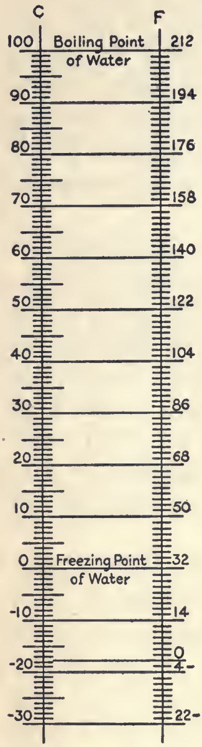
Experiment to Show Variation in Kindling Temperatures.—It is interesting to show the different kindling tem-

peratures of two or more substances, such as phosphorus, sulphur, wood and coal. To do so, place a sheet of wire gauze about a foot square on an iron ring stand. On the gauze put a small amount of each substance. **Caution:** *Keep the phosphorus under water until required and use only a small piece.* Observe for five minutes. Does anything happen to any substance on the gauze? Apply heat gradually under the gauze and notice the order in which the different substances kindle as the degree of heat increases. Remembering that the kindling temperature of a substance is the lowest temperature at which it will burn, what do you conclude in regard to the comparative kindling temperatures of these substances?

Smoke.—If there is not a sufficient supply of oxygen to burn combustible material completely, smoke is likely to form. This often happens when starting a fire or when using damp material. Smoke may occur for a little time after a large supply of fuel is placed on a hot fire. It is a sign of incomplete combustion. The rising gaseous products released by the heat become laden with minute particles of carbon and with other unconsumed bits of matter. Smoke, then, is a mixture of different forms of matter, some of which reflect the light and so make the mixture visible to us.

Spontaneous Combustion.—Sometimes fires which cannot easily be accounted for occur in buildings and result in great loss of property. In such cases, it frequently happens that their origin may finally be traced to some oily rags thrown into a closet where there is very little or no ventilation. These oily rags gradually become warmer as the oil oxidizes, until heat enough has accumulated to raise their temperature to the kindling point, and then the fire will start. This is *spontaneous combustion*—a fire starting as the result of oxidation without any outside aid. It sometimes occurs in hay barns where the newly cut grass is packed so tightly that it receives no ventilation. It also occurs in bituminous, or soft, coal piles where there is poor ventilation. This becomes a serious problem where much coal is piled together, as in the coal bunkers, or bins, of ships.

How Temperature Is Measured.—Temperature is most commonly measured by a thermometer. A standard form consists of a tube with a very small bore, called a capillary tube, with a bulb at the lower end. This tube is partly filled with mercury. The air is exhausted from the part above the mercury. The tube is sealed at the upper end and fastened on a metal or a wooden frame, with a scale indicating the different degrees of temperature. The action of this instrument depends on the expansion of the mercury as it warms and on its contraction as it cools.



Thermometer Scales Compared

The scale marked C is centigrade. The scale marked F is Fahrenheit. Compare the freezing and boiling points on the two scales.

Some thermometers contain colored alcohol in place of mercury. Others, used in measuring very high temperatures, are made of bars of copper or some other metal, whose expansion or contraction is recorded on a dial. These metal thermometers are often used on ovens.

Two thermometer scales are in common use. In this country we use for ordinary purposes the *Fahrenheit* scale. It has two fixed points: the boiling point of water, which is marked at 212 degrees, and the freezing point of water at 32 degrees. The space between these two points is divided into 180 degrees. Scales usually read far below 32 degrees. When the temperature goes below 0, we say it is so many degrees below zero, and use a minus sign to express it. Eight degrees below zero is written —8°.

In Europe the *centigrade* thermometer is quite generally used. On its scale the boiling temperature of water is placed at 100 degrees and the freezing temperature at 0 degrees. The space between these points is divided into 100 degrees. Temperatures below zero are marked minus (—). The centigrade thermometer is used in this country for most scientific purposes.

The temperature of a properly heated room, measured by a Fahrenheit thermometer, is about 68 degrees. A centigrade thermometer would read 20 degrees under the same conditions. This means that 20 degrees on the centigrade thermometer indicates the same temperature as 68 degrees on the Fahrenheit. To show which scale is meant, it is customary to place an F. after the Fahrenheit reading and a C. after the centigrade reading.

Physicians and nurses use a *clinical* thermometer. It is a mercury instrument having a Fahrenheit scale which reads from 92 to 110 degrees. Each degree is divided into fifths. In this instrument the mercury remains at the highest temperature recorded until shaken down. The normal temperature of a healthy person is 98.6 degrees; 100 degrees shows that he has some fever; 103 degrees or higher that he is seriously ill.

Experiment to Test the Fixed Points of a Thermometer. —To show how a thermometer indicates changes of temperature (testing of fixed points): Boil water in a beaker. Hold a Fahrenheit thermometer with its bulb in the boiling water for three minutes. Read the temperature. Fill a jar with small pieces of ice and a little water. Hold the thermometer bulb in the iced water for three minutes. Read the temperature. What are the fixed points of a Fahrenheit thermometer?

Effects of Heat.—The effects of heat are either physical or chemical. Important physical effects of heat are the causing of matter to expand, to liquefy or melt, and to vaporize or turn to gas. The most important chemical effect is to cause oxidation.

With rare exceptions, heat will cause matter, whether in a solid, a liquid or a gaseous state, to expand. Rubber is one exception, for it contracts when heated. Most liquids when heated expand more than solids do. Water, however, is an exception in some respects to the general rule of expansion. As we heat and cool it for daily use, this liquid seems to expand and contract like other forms of matter. But when cooled it contracts until it reaches 39 degrees F., the point at which it begins to expand when heated. At this point it begins to expand again, and continues to expand until it freezes. That this is so may be shown by freezing the water in a full bottle. As you

know, the bottle will break, due to the expansion of the water. This explains why water pipes burst and the cement sides of cisterns crack in very cold weather.

Water increases its volume over one-twelfth when it freezes. The water in a pond or a lake contracts as it cools until it reaches a temperature of 39 degrees F. Then it begins to expand until it reaches the freezing temperature. The ice is lighter than the water and so floats. Otherwise, ice would sink and if cold continued the lake would finally become solid ice. This would make a great change in the climate, and would destroy water life. This expansion is not true of most other liquids, as they continue to contract as they cool until they become solid.

Experiments to Show the Expansion of Three States of Matter by Heat.—1. To show that a solid will expand when heated, take a metal ball and a ring through which the ball will just pass when cool. Heat the ball and try to pass it through the ring. Explain the result.

2. To show that a liquid expands when heated, fill a large bottle with colored water. Insert through the center of a cork a glass tube about ten inches long until one end is level with the lowest part of the cork. Put the cork tightly in the mouth of the bottle and then push the tube down about an inch lower into the water. Heat the bottle gently over a Bunsen burner and observe the effect on the water. At first the height of the water in the bottle becomes a little less. Can you account for this? Afterwards, the water gradually rises and some passes up the tube, showing that water expands when it is heated.

3. To show that gas expands, heat water in a tea kettle and notice that as the water boils the cover of the kettle, if set loosely, bobs up and down, and steam escapes. Steam is a gas. As it rises from the water it expands and exerts a pressure which lifts the cover and allows some of the steam to escape; when the pressure is released the cover drops back. This is another illustration of heat transformed into motion.

Variation of the Boiling Temperature.—The boiling temperature of a liquid is reached when the motion of the molecules within the liquid becomes so great that they get far enough

apart to break away and form a gas. In order to do this, they must overcome the air pressure. In high altitudes, the boiling temperature of liquids is lower than at sea level as the air pressure is less, and so the molecules do not have to move so fast to break away from the liquid and go off as a gas.

Fuels.—There are, perhaps, no more important industries than those which provide fuels for households and industrial plants.

Brown Brothers.

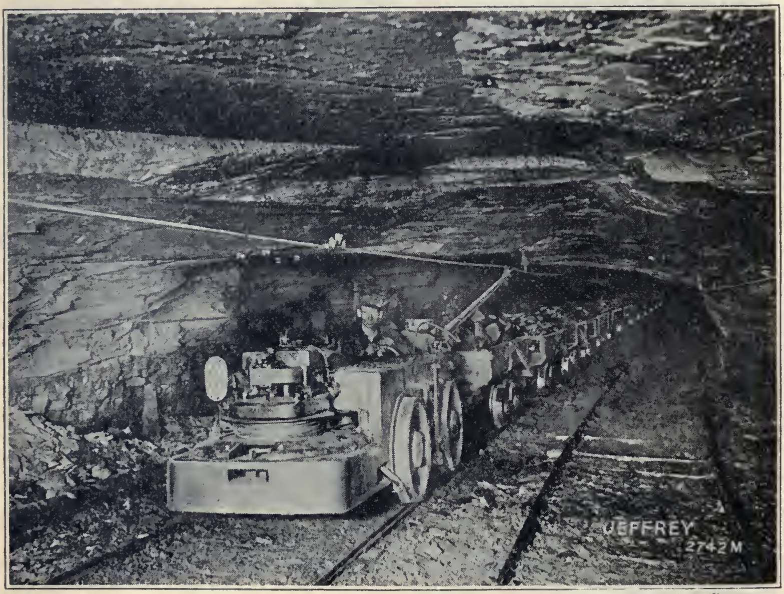
FROM SUCH FORESTS COAL WAS FORMED

Fuels are usually classified as *solid, liquid,* and *gaseous. Wood, coal, peat, charcoal* and *coke* are solid fuels. *Gasoline, naphtha, kerosene, alcohol,* and *fuel oil* are liquid fuels. *Coal gas, water gas, gasoline gas* and *acetylene gas* are gaseous fuels. All of these are composed largely of two elements, carbon and hydrogen, upon which depends their usefulness as heat producers.

It is thought that wood was the first fuel used by man. Wood is composed chiefly of water, starch, gum oil, cellulose, and resin,

all of which consist largely of the elements carbon, hydrogen, and oxygen. Wood also contains various minerals. The flame we see in the process of combustion is due to the burning of vapors or gases which are released from the wood by heat.

Coal.—Coal is composed largely of carbon. Ages ago it was formed from large trees and other luxuriant growths of vegetation that died and became covered with water in the swampy places where they grew. As water kept the air from their tis-



United States Geological Survey.

BRINGING COAL FROM THE MINE

sues, they did not readily decay. Eventually they became covered with earth, and new forests with smaller forms of plants grew over them. These, in turn, died and were covered by rocky materials. This continued for ages, until the pressure and heat due to this covering became great enough to change the vegetable matter into coal. The vegetable matter under the greatest pressure and heat became hard, or *anthracite*, coal; while that under less pressure and heat became soft, or

bituminous coal. Anthracite coal is found in mountainous regions.

Hard coal is especially desirable for household purposes since it burns with little or no flame and is nearly pure carbon. Soft coal is used largely for industrial purposes. It contains many carbon compounds and burns with a yellow flame. As it produces much soot and smoke, it is not desirable for household purposes, though it may be so used.

Peat.—Peat is a substance of vegetable origin composed of moss, twigs and roots of trees in various stages of decay. It is found as a kind of turf in places that were once swamps or the borders of lakes. Peat bogs are found in many parts of the earth. Some of them in Ireland are said to be over forty feet deep. The turf-like substance is dug out of the bog, dried, pressed into blocks and used as fuel. Most of the carbon of this former vegetation, which in the air would have been oxidized into carbon dioxide, has been preserved under water in the swamps and therefore makes good fuel.

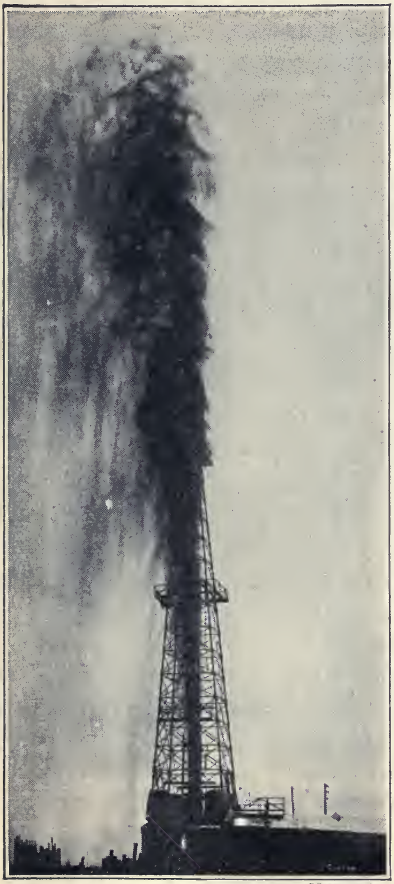
Charcoal.—Charcoal is nearly pure carbon. It is made by putting wood into closed, air-tight chambers, called retorts, and subjecting it to heat. By this process the wood is changed into a porous black solid, which burns very easily. When burned, it produces intense heat. In making it, certain valuable by-products are yielded, among which is wood alcohol.

Coke.—Coke is manufactured from soft coal in much the same way that charcoal is made from wood. In producing it, by-products are yielded, among which are illuminating gas, creosote, benzene, carbolic acid and ammonia. Coke is largely used as a fuel and in separating metals from the ore in which they are found.

Liquid Fuels.—The liquid fuels, kerosene, gasoline, naphtha, fuel oil, and alcohol, are combustible materials called ***hydrocarbons.*** They are compounds of carbon and are made from petroleum, a crude, dark, bluish-brown, oily substance, obtained from the depths of the earth. The petroleum is boiled and its vapor collected and then condensed to liquid by cooling. You can easily understand this by recalling how the steam of boiling

water returns to liquid form when it strikes a cold surface. The whole process is called *distillation*.

Kerosene was used extensively, and is still used to some extent, for lighting, heating and cooking.



International Newsreel.

AN OIL GUSHER

Rock pockets under the earth sometimes contain natural gas and oil. When piped, the gas pressure may drive the oil to the surface with tremendous force.

Gasoline is used to generate the power necessary for the operation of automobiles and other motor-driven machines.

Naphtha is used to supply light, and as a cooking fuel.

Fuel oil is used in furnaces, kitchen ranges, and some types of motors.

Alcohol, another liquid fuel, is used to some extent in laboratories to produce heat.

Gaseous Fuels.—The gaseous fuels, coal gas, water gas, gasoline gas, acetylene gas, and natural gas are extensively used. Coal gas is produced by distilling soft coal in retorts from which all air is excluded. The bright flame with which coal gas burns is due to the presence in it of hydrocarbons. Water gas is a mixture of carbon monoxide and hydrogen. It is used for lighting purposes in some places, after some form of hydrocarbon has been added to it to render the flame luminous. Gasoline gas is a mixture of air and gasoline vapor. Acetylene gas is generated from calcium carbide and water. The gas is allowed to escape

into a gas holder from which it is conducted by pipes to the place where it is to be used. It burns with a white light, said to be a near approach to sunlight.

How Heat Is Measured.—The amount of heat required to raise the temperature of matter, such as water or other material, may be measured. Just as the gallon is used as the unit in measuring quantities of water, or the bushel in measuring grain, there is a unit of measure for measuring heat. This unit is called the *calorie* from the Latin word calor, meaning heat. A calorie represents the amount of heat necessary to raise the temperature of one gram of water one degree centigrade. It is used in scientific work and in measuring the amount of heat given off in burning various substances. In measuring the heat values of foods and fuels, however, the large Calorie (C) is used. This is 1,000 times larger than the small calorie (c).

Here is a table which shows the approximate heat values of certain fuels:

	Calories (C) per Pound of Fuel
Carbon	3672
Hydrogen	15664
Various kinds of wood	2141 to 2300
Charcoal	3227
Peat	1800 to 2300
Soft coal	3000 to 3600
Hard coal	3400 to 3900
Coke	3450 to 3700
Petroleum	around 5000

Conservation of Fuel.—Nature has been so liberal in the production of fuel material that man has seemed to think it will always last. Accordingly he has mined coal in a wasteful manner, allowed natural gas to burn needlessly, and destroyed the forests for commercial purposes without replacing them with new growths, called *reforestation.* Now that scientists estimate that the available coal supply will be exhausted in the course of about one hundred years, that oil wells are exhausting the oil supply, and that reforestation is not as extensive as is necessary to provide for future use, it would seem that all persons should conserve fuel as much as possible.

Fire Dangers and Losses.—As long as fire is kept under control it is a very useful servant, but whenever it gains such headway that it cannot be held in check, it mercilessly burns nearly all things with which it comes in contact. It is, therefore, important to remove or guard all fire hazards in the home, the school, the factory and the theatre; in fact, in all buildings. That there is not sufficient attention given to this is proven by the great losses each year from fires that might have been prevented with care. Every year many buildings are destroyed because authorities in charge of them have not exercised adequate care in looking for fire hazards and in removing them when found. These dangers may be caused by the throwing of old cleaning rags into a closet, the leaving of some combustible material too near a furnace in the basement, or by some other careless act.

Removing a Fire Hazard

Fire Exits.—In case of fire, the regular doorways are sometimes inadequate, or are even entirely cut off by the flames. It is therefore necessary to have other exits by which to leave a burning building. If above the first floor, such exits are commonly connected with a fire escape which consists of a stairway on the outside of the building, or a chute, somewhat like those seen on playgrounds, by which a person can slide to a place of safety.

All exits and escapes should be regularly inspected to see that the doors leading to them are not locked and that the stairs or chutes are not in any way blocked. In schools, regular fire drills are required by law. These drills are desirable in factories and in all buildings where a large number of people assemble daily, but they are not always required by law and often are not held.

Such drills would undoubtedly prevent much loss of life when large fires occur.

Fire Prevention.—Fires may often be prevented by due caution on the part of those in charge of buildings. Often fires start from lamps or small stoves that explode because they are not properly cleaned. The person in charge should see that they are kept in good condition. He should never allow kerosene or other inflammable liquid to be poured on fuel already ignited. He should examine all chimney flues and all heat pipes leading from a furnace to make sure that they are in good order before he builds a fire.

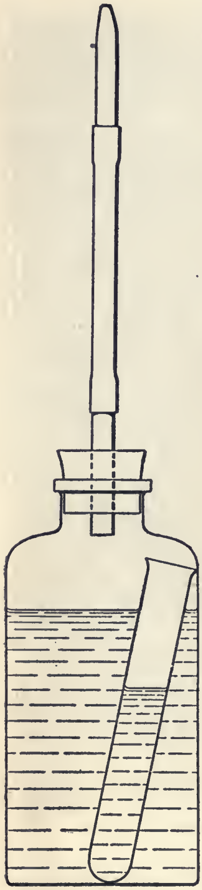
Underwood & Underwood.

A Modern Fire Escape

Fire Extinguishers.—In spite of all precautions, drapery or other material in a room will sometimes accidentally catch fire. In such cases, the use of a fire extinguisher will often prevent the spread of the flames. Everyone should understand the structure, principle and use of this safety apparatus.

Experiment to Show Structure and Use of a Fire Extinguisher.—A good way to learn about a fire extinguisher is to make one and use it. This may be done with a wide-mouthed bottle, a solution of bicarbonate of soda, a test tube, some sulphuric acid, a one-hole rubber stopper for the wide-mouthed bottle, a glass tube, a few feet of rubber tubing, a tin can, match sticks and paper.

Fill the wide-mouthed bottle three-fourths full of the solution of bicarbonate of soda. Nearly fill the test tube with sulphuric acid and place it in the wide-mouthed bottle, in such a way that the liquids will not mix when the bottle is upright. Insert the glass tube in the stopper. Attach the rubber tube to the upper end of the glass tube. Place the stopper in the wide-mouthed bottle. Then tip the bottle so as to empty the contents of the test tube into the bicarbonate solution. Notice that a gas is formed. It is carbon dioxide, which forces the soda solution through the tube. Play this solution upon a small fire made in the tin can, and note the result.



A Simple Fire Extinguisher

Fire extinguishers should be placed at danger points in home or school. They should be inspected and refilled every year.

Fire and Fire Fighting.—The fire losses in the United States total more than one-half billion dollars per year. A large percentage of these fires is caused by carelessness. The smoker throws away a lighted match, the painter leaves an oily rag where there is poor circulation of air around it, or an electrician does a poor job of wiring. Most fires could be prevented with proper precaution.

There are two general methods of fighting a fire. One method is to blanket it, thereby shutting out the air and thus smothering the fire. The old-time method of throwing dirt over burning material is an example of the blanketing method. The other method is to cool the burning material below the temperature at which it takes fire. The most common extinguisher used in the cooling process is water. When the water strikes the burning material it instantly turns to steam and in so doing uses up much of the heat that is necessary to keep the fire going. Extinguishers containing

bicarbonate of soda or certain other fire-extinguishing solutions, such as calcium chloride, also depend upon the cooling principle for their effect.

Special methods are necessary in fighting serious oil fires because the oil is lighter and will float on water and many other extinguishing agents. A method has been developed in recent years which is very efficient in fighting oil fires; it is called the

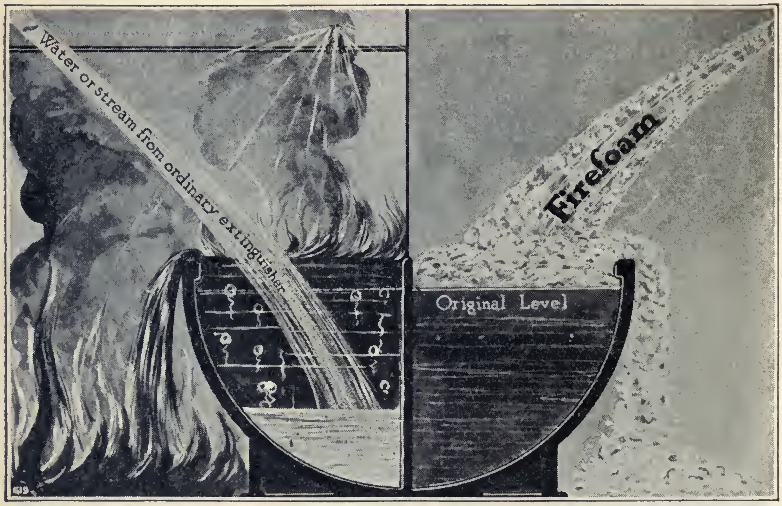
Underwood & Underwood.

FIGHTING FIRE

"Firefoam" method. Chemicals are placed in separate compartments, as in the soda and acid extinguisher. When the extinguisher is inverted, the chemicals mix and the action that follows gives off a foam which is made up of small bubbles filled with carbon dioxide. This foam is very light and will float on the surface of the oil. It is a very poor conductor of heat so that

nothing above it will get hot enough to take fire. It lasts long after the fire has been extinguished.

Another very common fire-fighting liquid is carbon tetrachloride. It is sold under other names, such as "pyrene" and "carbona." This liquid vaporizes easily and, when warmed by



Foamite-Childs Corp.

FIGHTING FLAMING LIQUID

Note that the water is heavier than the burning liquid and so sinks below, leaving the flames unextinguished.

The foam is very light and floats on the surface of the burning liquid, forming a blanket which smothers the flames.

the fire on which it has been thrown, will turn to a gas. This gas will not burn but lies over the fire, forming a blanket which shuts out the air, smothering the flames.

SUMMARY

All heat comes originally from the sun which gives it off in enormous amounts.

Heat is the result of the motion of molecules. It is a form of energy.

Effects of heat are physical, as when it causes matter to expand or change its state, or chemical, as when it causes oxidation.

The kindling temperature is the temperature at which a substance will take fire.

Temperature is measured by means of an instrument called the thermometer.

The most important kinds of fuel are wood, coal, charcoal, peat, alcohol, oils and certain gases.

Wood, coal, charcoal, peat, and coke are composed largely of carbon.

Liquid fuels, such as kerosene, gasoline, naphtha, fuel oil, and alcohol are combustible materials called hydrocarbons.

The principal gaseous fuels are coal gas and water gas.

The unit of heat measure is the calorie. It represents the quantity of heat required to raise one gram of water one degree centigrade. The large Calorie, used in measuring the heat values of foods, represents the amount of heat required to raise 1,000 grams of water one degree centigrade or one pound of water four degrees Fahrenheit.

The dangers of uncontrolled fire are great. Fire exits, fire drills, and other means of fire protection should be provided in schools and in all buildings where large numbers assemble.

Fire extinguishers are of two types, those which act as cooling agents and those which form a blanket shutting out the air.

Fact and Thought Questions

1. Mention effects of heat you have noticed in your own home.
2. How may heat be liberated without fire?
3. What is meant by the kindling temperature?
4. Describe several ways in which fire is produced.
5. Explain the origin of coal. Of peat.
6. How is coke produced? Charcoal? Coal gas?
7. Complete, orally, the following statements:
   (a) A thermometer is ——.
   (b) A degree Fahrenheit equals —— of a centigrade degree.
   (c) The original source of heat is ——.
8. Why are smoke and fire sometimes produced when we drive an automobile with brakes on?
9. Why does the smoke of a fire decrease as the flame increases?
10. Why does a smouldering fire blaze up when stirred?
11. Give reasons for conserving fuel resources.
12. Name avoidable causes of fire in buildings.

13. If a small fire starts in a home, is it advisable to open or to close the windows? Why?
14. What should you do if your clothing catches fire? If that of a companion catches fire?
15. Why is it not possible to put out an oil fire by throwing water on it?

Projects

1. Make a fire by striking a piece of flint with steel.
2. Make and use a small fire extinguisher.
3. Note news records of fires for a period of three weeks, making a record of the known causes. Suggest methods of prevention.

Outdoor Observation

1. Build a small fire in a safe place. Note (a) effects of wind; (b) combustion of different materials; (c) effects of earth or of water in putting it out.
2. Provide yourself with an ordinary thermometer and a note book, and take a walk in your neighborhood. Take the air temperature at different points—in hollows, on hills, in the shade, and in the sun. Take the temperature of any running water you pass, or any still pool. Record observations, with conclusions as to causes for differences in temperature readings.
3. Observe and report on different types of fire escapes and exits in schools and in large buildings.

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CHAPTER VIII

SOME APPLICATIONS OF HEAT

After man had discovered fire it took him ages to learn to control the heat energy fire created, and so to make it a servant to warm his home and to supply force to help build and drive great machines.

Heat, man found, showed a great tendency to escape from its source. It might seemingly leap from the fire to scorch his face, yet leave his back chilled. It might travel the length of a crude iron bar, from the end in the flame, and burn his hand. It might actually flow about his hut in currents, or might flow upward and escape through a roof opening, leaving him unwarmed.

First, man built his fire on the ground. Then he invented an open fireplace and chimney, and after centuries he designed stoves to hold his fire for cooking and for warmth. Finally, using the tendency of certain heated matter to flow, and of other matter to radiate heat, he learned to build his fire in a furnace and pipe heat in the form of hot air, water and steam in quantities both large and small to provide for the heating of all types of buildings. All these improvements resulted from a knowledge of the laws of matter and energy as related to heat.

Heat is energy resulting from the motion of molecules. This motion is passed on from molecule to molecule and from object to object, and tends to diffuse, or spread out, until the places and objects where heat is present have the same temperature. You have undoubtedly noticed that when your hand is cold it becomes warmer by taking hold of an object which is warm. The heat moves from the object into your hand. If matter having a low temperature is placed in warm surroundings, it will absorb heat until it becomes as warm as the other objects around it.

Ways in Which Heat Moves.—Heat moves or is transferred from object to object in three ways: by *radiation,* that is, by passing in straight lines through space from one object to

another object; by *convection,* that is, by movement of currents in gases and liquids; and by *conduction,* that is, by transmission of heat from one part of a body to another part or from one body to another by direct contact.

Radiation.—If your feet are held in front of the burning wood in a fireplace they become warm. Heat passes out in all directions from the fire without the help of surrounding objects. It reaches your feet without any visible means. This method of heat movement is called radiation. Heat radiates from its source in straight lines and in all directions.

The sun's heat, called *radiant* heat, reaches the earth by radiation. Some investigators claim that it travels as fast as light, 186,000 miles per second. It is a curious fact that the heat from the sun will pass through transparent material, such as glass, without heating it. This may be shown by feeling the glass of a window when the sun is shining brightly on it.

The florist takes advantage of this fact by growing his plants in a glass-covered house, called a greenhouse. The rays of the sun travel through the panes of glass, and the objects inside are thus warmed. The glass will feel cold.

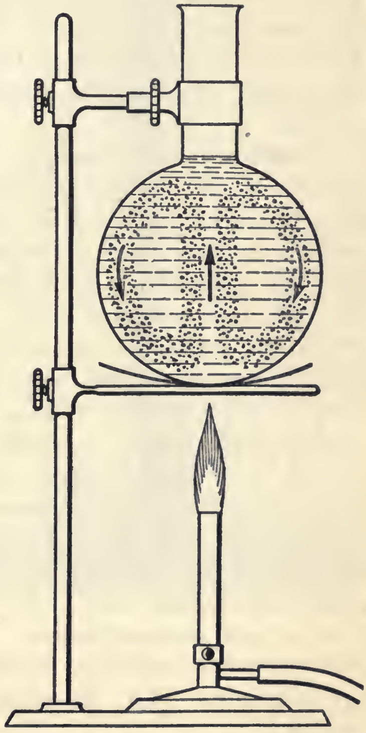
Radiant heat in its passage through the air from the sun to the earth does not heat the air, as is proved by the fact that the upper layers of the atmosphere are cold. The lower layers are not heated by these rays as is often supposed. They derive their heat by coming in contact with the heated surface of the earth.

The amount of heat that any body throws off by radiation depends on its substance, its surface, its color and its size. As a rule a substance that absorbs heat readily radiates it readily. A rough surface radiates more heat than a smooth surface. Hence radiator surfaces often have a rough finish. A black object radiates more heat than one of any other color. This is one reason why stoves are usually black. A large surface radiates more heat than a small one. For this reason, stove pokers often have coiled wire handles, instead of solid handles, affording more radiating surface and therefore giving off much of their heat before it reaches the hand.

Experiment to Show Radiation.—To show the transference of heat in matter by radiation, suspend a small heated ball in the middle of a room so that it will be a few feet above the floor. By several trials, find out in what directions and at what distances your hand will feel the heat without touching the ball. Is the heat given off equally in all directions, upward, downward and sideways? What conclusion may be drawn from this experiment?

Convection. — Convection is the transfer of heat by the flowing of gases or liquids. It depends for its effect on the fact that liquids and gases expand when heated and tend to set up currents within themselves. These currents serve to carry the heat to other portions of the gas or liquid.

Experiments to Show Convection.—To show the circulation of water by convection currents due to its unequal heating, place a small amount of fine sawdust in a flask and partly fill the flask with water. Heat the water gradually and notice what happens. Why does the sawdust act as it does? The upward movement of the water forms convection currents. This may also be shown with magenta crystals instead of sawdust. With these a colored effect is produced.



CONVECTION CURRENTS IN A LIQUID
As the water heats, it rises, carrying the sawdust with it.

To show that air expands when heated, partly fill a small bottle with eosin solution or some other colored liquid. Close the

mouth of the bottle with a cork through which passes a narrow glass tube reaching to the bottom of the bottle. Heat the bottle gradually. The colored liquid will rise in the tube. This is caused by the expanding of the air.

To show the transference of heat in matter by convection, hold a burning joss stick under a good-sized inverted glass jar. The movements of the air will be indicated by the smoke. These movements are convection currents. Water and air expand when warmed, and in each case convection currents are caused by this expansion. Without this expansion convection would be impossible.

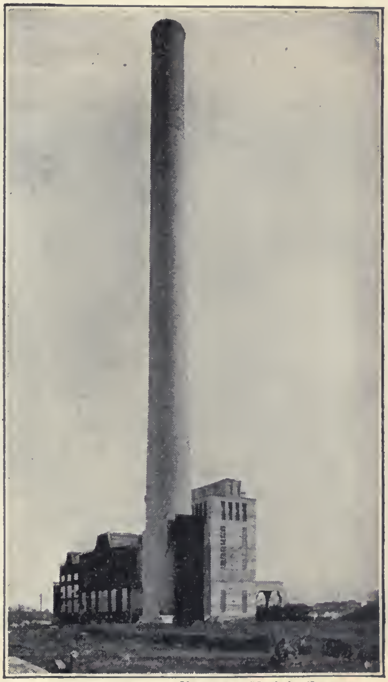
Conduction.—Conduction is the process of transferring heat by contact. In order to understand the difference between conduction and convection it is necessary to keep in mind that all bodies are made up of molecules. In conduction, each molecule heats the neighboring molecules by striking against them, and thus the heat is passed along from molecule to molecule. In convection, masses of molecules, when heated, start moving and other masses, less heated, move in to take their place. Thus currents are set flowing, and these carry the heat.

Experiments to Show Conduction.—To show the transference of heat by conduction, place one end of an iron rod about a foot in length in the flame of a lamp or burner. Hold the other end in your hand until you feel the heat. Try the same experiment with a glass rod of the same length as the iron rod. Experiment with wooden and copper rods of the same length, and with rods of other substances. Is the heat felt on the hand as soon with one substance as with another? If not, what do you conclude? Why is copper a good material for cooking utensils?

Methods of Heating Buildings.—There are five important ways of heating buildings: by the *fireplace,* the *stove,* the *hot air furnace,* the *steam heater* and the *hot water heater.* All of these require a fire and, therefore, a chimney.

Importance of the Chimney.—In early times houses were heated by building a fire on the floor. A hole was left in the roof through which much of the smoke passed out, though some

stayed in the house. It was discovered that the smoke caused less unpleasantness and escaped more readily if not allowed to spread. This led to the invention of the chimney, which is merely a long tube, leading from the fire through the roof, up which smoke and gases pass owing to the formation of convection air currents. These make a movement of air called a *draft*. If the air in the chimney is warmer than the outside surrounding air the draft carries the smoke and all gases upward and out the top opening of the chimney. Whenever a fire is started in a stove the heated air immediately causes a draft upward. In order to work to the best advantage, a chimney should be straight and should have a smooth inside surface. The efficiency of a chimney increases with its height.



Eastman Kodak Company.

A Tall Chimney

The taller the chimney, the better the draft.

The Fireplace. — Our forefathers used the open fire extensively. The old-fashioned fireplace, built of brick or stone, was usually about five to eight feet wide and two to three feet deep. Large logs of wood were used for fuel. Most of the heat went up the huge chimney. The small part that was left spread through the room by radiation and convection.

In the old days the fireplace was used not merely for heating; it was the only means of cooking food. Potatoes were roasted in the coals, and meats and vegetables were cooked in pots and kettles hung on an iron crane so attached to the wall of the fire-

place that it could be swung into it or out into the room. Bread was baked in a large oven built in the side of the fireplace.

The fireplace of today is smaller or is replaced by the modern grate. This burns much less fuel than the old-fashioned fireplace. In warm climates it is frequently the only method of heating the living-room. In cold climates it is usually used to supplement a hot air heater or some other system of heating.

Underwood & Underwood.

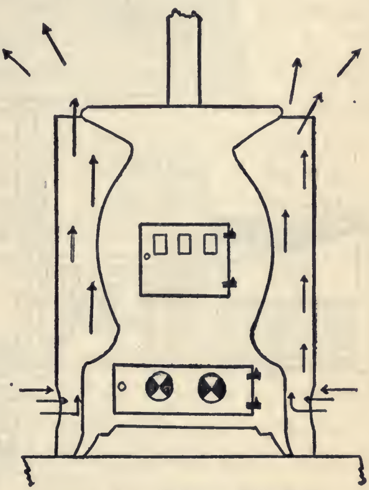
A Colonial Fireplace
Around it centered the activities of the home.

The Stove.—The first stove was simply an iron box having a door in one end and a hole in the top for the escape of the smoke into the chimney. Stoves of this kind were used in colonial times in this country. As early as 1742, Benjamin Franklin invented what he called "an open stove for the better warming of a room," but it is only about a century ago that stoves were generally introduced into our homes. Previous to this there was little warmth in any room except the living-room, as the fireplace was the only means of heating. Other rooms in the house were

cold and damp in winter. This was especially unpleasant in sleeping rooms. The coming of the stove was a great blessing to mankind.

All the ways in which heat is transferred are illustrated in the use of stoves. Convection, however, is the most important way in which the heat of stoves is distributed. The air over the stove becomes heated and rises. Striking the ceiling, it is turned aside toward the four walls, where it is cooled more or less according to the number of windows in the room. As it cools, it becomes heavier and, settling to the floor, flows back to the stove where it is rewarmed and the process repeated. A general circulation of the air is maintained as long as the fire burns.

The Jacketed Stove.—A wall of sheet iron is often placed around a stove to prevent too much radiation. Such a stove is said to be jacketed. It is frequently employed in schoolrooms to insure proper distribution of heat. When the cold air enters at the lower part of the jacket, convection currents are set up which carry the air, heated by the stove and the jacket, throughout the entire room. When the stove is not jacketed it overheats all objects near it, while objects in the farther parts of the room remain cold. As a result, pupils sitting near an unjacketed stove in a schoolroom suffer from too much heat while those sitting in the farthest parts of the room suffer from cold.

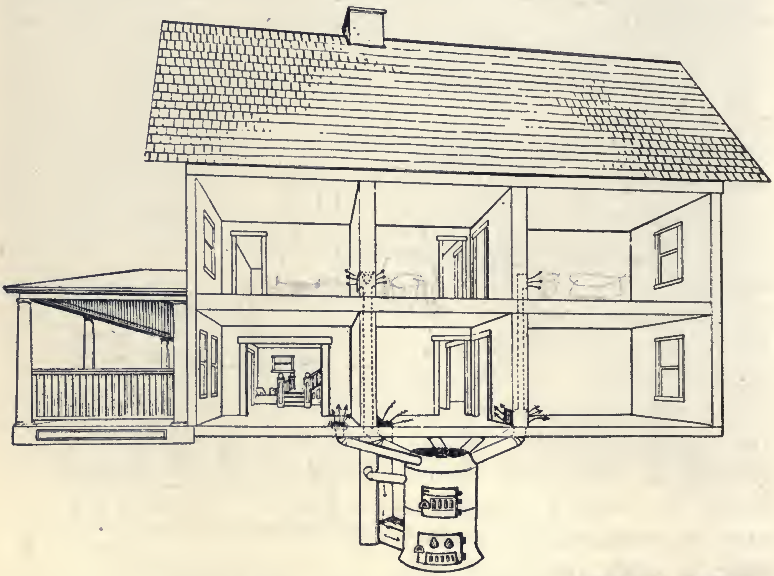


A JACKETED STOVE
Notice how the cool air rushes in to take the place of the warm air which rises.

Hot Air Method.—In using the hot air method, a furnace is installed, usually in the basement of the house. A furnace is a stove entirely surrounded by a metal jacket. Air pipes lead

from the furnace to grated openings, or registers, in the rooms to be heated. The efficiency of this method depends upon convection currents. The same principle is used as in the jacketed stove. Cold air enters the bottom part of the jacket, is warmed, and rises through the pipes into the rooms.

The cold air, in the best heating plants, is brought from the outside of the building through an inlet called a cold air box. In large buildings it is often forced in by motor-driven fans. In small buildings enough cold air flows through the inlet to replace the warmed air which is passing up the pipes.



International Heater Co.

A Hot Air Heating System
Trace the flow of air currents.

The air used in a hot air heating system should be moist. This is accomplished in large plants by means of an apparatus called a *humidifier,* or moistener, over which the air passes before it reaches the rooms. In homes, the furnace is usually provided with a water container from which sufficient moisture evaporates, if it is kept filled with water.

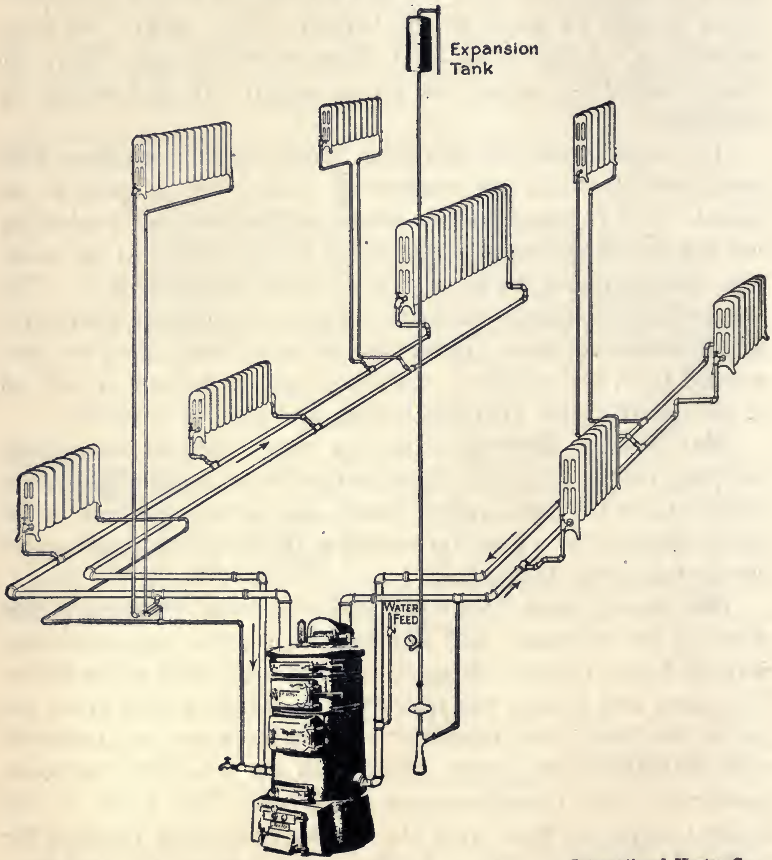
Steam Heating Method.—In using the steam heating method, a steam boiler is installed in the basement of the building. This boiler is connected, by means of pipes, with radiators in the rooms to be heated. There is a set of pipes through which the steam ascends to the radiators and through which the condensed steam returns as water to the bottom of the boiler. In large buildings it is often necessary to have more than one boiler. In rooms heated by steam, the air is usually dry and should be moistened.

The radiator surface in a room should contain in square feet about one-fiftieth of the number of cubic feet of space to be heated. The radiator itself is heated on the inside by conduction and the heat flows through the metal to the outside in the same way, thus warming the air which comes in contact with it. The room is heated partly by radiation, partly by conduction, but largely by convection currents. These convection currents carry the heat upward from the radiators, and other similar currents are set up in the rooms by the alternate heating and cooling of the air.

Hot Water Method.—The hot water method of heating buildings differs from the steam method in having the boiler, the radiators and the pipes full of water, and in having a tank in the attic, connected by a pipe, for receiving the extra volume of water due to expansion by heating.

One set of pipes connected with the boiler carries the hot water to the radiators, and another set of pipes, also connected with the boiler, conveys the water, after it cools, back to the boiler. The pipes that convey the water to the radiators start from the top of the boiler, and those which return the water are connected with the boiler at the bottom. In the hot water method, radiation, conduction, and convection are employed. The water in the boiler receives its heat from the fire by conduction through the walls of the boiler. When the hot water reaches the radiators, the cold iron immediately takes up some of the heat, passing it through the iron by conduction to the air in the room to be heated. Convection currents are at once formed. Although considerable heat leaves the radiator by radiation, much of it is carried by these convection currents.

In using this system, it must be kept in mind that the pipes will burst in cold weather from the freezing of any water left in them after the fire in the boiler has gone out. Therefore it is wise to drain the pipes whenever the plant is not in use. For



International Heater Co.

A HOT WATER HEATING SYSTEM

Trace the course of the water in each circuit.

this reason, also, the valves of the radiators should never be closed in very cold weather since this would prevent the entrance of hot water into the radiators.

The expense of installing the hot air system is less than that of either hot water or steam. It takes up less space in the rooms since there are no radiators. There is no danger from freezing as there is no water in the pipes. On the other hand, the hot air system is more or less affected by strong winds which often prevent the uniform heating of a house.

Hot Water Boilers.—Many homes have hot water boilers which are filled from the water supply system. A pipe extends from the bottom of the boiler to the heater and then back to the boiler. As the water in this pipe is heated convection currents are set up which carry the hot water to the top of the boiler where it may be drawn off through a pipe leading to the faucets.

Care of Heating Systems.—In running any type of heater, care should be used to keep the fire free from ashes and clinkers and to spread fresh fuel evenly. Drafts should be so regulated that combustion is as complete as possible, and that unburned gases are drawn up the chimney. Often a thermostat is used, a device which automatically regulates the heat of the house by controlling the drafts. It is essential to keep sufficient water in the boiler of a steam heater, to keep the expansion tank of a hot water heater open, and to keep the water pan of a hot air furnace filled. In freezing weather, with fires out, all water pipes and boilers should be drained.

Ventilation.—Ventilation is the changing or renewing of the air supply. It is closely associated with heating. The modern theory of ventilation teaches that constant movement of air of proper temperature, and containing a proper amount of moisture, is the main thing in good ventilation. A person is more comfortable in a room having a temperature of 65° with moist air than in a room heated to 70° with little moisture.

Air contains a certain amount of moisture. This may be measured and is usually expressed as a per cent of the amount that the air could hold at the same temperature. If the air in a room at a given time has only 50 per cent of the moisture that it can hold, it is said to have a relative humidity of 50 per cent.

Cold air will hold very little moisture, while warm air will hold a great deal. When the cold air is taken from the outside

and warmed by the furnace, it becomes very dry; that is, the relative humidity becomes very low. This makes us feel chilly, and we increase the fire. There are several devices on the market today for adding the proper amount of moisture to the air in rooms.

Most persons are afraid of drafts in a room, but Dr. W. A. Evans of Chicago, after a careful study of the relation of air motion to ventilation, says that "a drafty room is a healthful room." Of course he means a room where convection currents keep good air of proper temperature in motion, and not a room into which outside winds are blowing.

Systems of Ventilation.—There are two general methods of ventilation: the *gravity system* and the *forced system.* In the gravity system, fresh air is introduced into a building through windows and doors, or by means of air shafts. In the forced system, the air is blown into the building, or is drawn in by suction, by means of fans, or by a combination of the two.

The old time fireplace, while it did not give a uniform distribution of heat, provided excellent ventilation. The warm air flowing up the chimney always caused convection currents in the room where the fireplace was located. In rooms heated by stoves, fresh air is commonly introduced by opening windows and doors. A circulation is kept up since the fresh air moves in to take the place of the warm air as it rises over the stove. If a pail of water is near the stove, considerable moisture will usually pass from it in the form of water vapor to render the air healthful.

A gravity system that works well in cold weather sometimes is not satisfactory in mild weather, for then the temperatures of the outside air and of the inside air are so nearly equal that an adequate convection current is not produced. In such a case it may be necessary to heat the air in the shaft or flue by means of a stove in the basement.

When steam or hot water is used for heating, a building may be ventilated by the indirect radiation system, or by the direct-indirect radiation system. In the first method, coils of steam or

hot water pipes are installed underneath the floor. They are enclosed in boxes which are connected with the outside by means of long flues through which fresh air enters. As it flows into the boxes and comes in contact with the heated coils, the air is warmed and rises through grated openings into the rooms.

In the second method, the direct-indirect system, the radiators in the rooms to be heated are usually placed near the windows. The fresh air enters the building from the outside through an opening in the wall and is conveyed to openings in the floor under the radiators in each room. As air passes over the heated radiator, it becomes warm and carries the heat by convection currents around the room.

When the air is blown into a building by force, the method is known as the *plenum system,* and when it is drawn in by suction it is known as the *vacuum system.* In the plenum system the fan is generally installed in the basement. In the vacuum system, it is commonly installed in the attic. By the plenum system the air is forced over the heated surfaces of coils of pipe and then through air passages into the rooms. By the vacuum system the fan draws out the foul air, and fresh air is pushed into the air passages by the pressure of the outside atmosphere. Sometimes the two systems are combined in order to make ventilation more effective.

In buildings where there is no system of ventilation, fresh air may be secured and foul air gotten rid of by merely opening the windows at the top and bottom. By this method convection currents are set up which are quite effective in changing the air of a room.

Experiment to Show, by the Use of a Model, a Good Method of Ventilating a Room.—Prepare a box about two feet long, eighteen inches high and six inches wide, with a sliding glass front. To represent windows, bore four ¾-inch holes in each end, two in the upper and two in the lower part. Fit a cork in each opening. In the box, about six inches from each end, set two lighted candles. Close the glass front. Then (a) open the holes in the lower part of one end and in the upper part of the other

end of the box, and test the currents of air by placing smoking joss sticks at the openings; (b) open all the holes on one end, leaving those on the other end closed, and test in the same manner; (c) open all the holes in the lower part, leaving the upper holes closed, and test as before; (d) open all the holes in the upper part, leaving the lower holes closed, and test. Which method gives the best ventilation?

The Fireless Cooker.—A fireless cooker is a box into which hot food is placed to cook without the further use of fire. It is made of materials which do not readily conduct heat. It consists of an ordinary box within a larger box whose bottom and sides and top are from four to six inches thick and made of, or packed with, paper or with some other non-heat-conducting material. After the food to be cooked is brought to the desired temperature by heating, it is placed in the box and tightly covered. Since the heat escapes very slowly, the food is kept at about the same temperature it was when put in the box and continues to cook. A piece of soapstone may also be heated and placed in the box below the food to give added heat.

THE FIRELESS COOKER
It cooks hot foods by their own heat.

The main objects in using a fireless cooker are to save fuel and to lighten the burdens of the housekeeper. A fireless cooker is not an expensive article. Any family wishing to use one can make it by securing two boxes of proper size and the necessary packing material.

The Vacuum Bottle.—The vacuum bottle works on somewhat the same principle as the fireless cooker. It consists of a glass bottle inside of a larger bottle and sealed to it at the neck. By creating a vacuum in the space between the two bottles, that is, by removing the air, it becomes impossible for

heat to pass rapidly to or from the inside bottle. A hot liquid poured into it will therefore remain hot, and a cold liquid will remain cold for a long time if the covering of the bottle is tight.

Any device, such as a fireless cooker or a vacuum bottle, which keeps food hot for a considerable period of time, must do so by holding the heat that is placed in it with the food, as it has no means of forming heat. We have learned that heat may be transferred from place to place by any one or more of three methods; conduction, convection and radiation. The efficiency of the vacuum bottle depends upon eliminating to a large extent these methods of heat transfer.

The vacuum bottle is made of glass, which in itself is a poor conductor of heat. There are two walls of glass, and the space between them is a vacuum. A vacuum will not conduct heat. Thus loss by conduction is almost entirely eliminated.

Landers, Frary & Clark.

A Vacuum Bottle

A bottle within a bottle, separated by a vacuum. Hot liquids in the inner bottle will keep hot, and cold liquids will keep cold.

A vacuum also eliminates the loss by convection because convection depends on the circulation of a gas or a liquid and neither exists in a vacuum.

Radiation may be reflected from a mirror. Both sides of the glass next to the vacuum in a vacuum bottle are silvered as mirrors are. Radiation from within the bottle is thus turned back. The silver coating on the inside of the outer wall reflects outward all radiation coming from the outside which might change the temperature of the contents of the bottle.

About the only heat loss in the vacuum bottle is through the cover. Air or liquid inside the bottle may carry heat by convection and thus carry heat to the cork. It will then be conducted slowly through the cork and escape. When the bottle is filled with a cold liquid the conduction through the cork is reversed. In either case this transfer of heat is very slow.

SUMMARY

Heat tends to diffuse and thus equalize the temperature of all places and objects with which it comes in contact.

Heat is transferred by radiation, by convection, and by conduction.

In radiation heat passes from its source in straight lines.

In convection heat moves from place to place by the flow of a liquid or a gas.

In conduction heat passes from one object to another by contact.

There are five important modern ways of heating buildings: by the fireplace, the stove, the hot air furnace, the steam heater and the hot water heater.

The fireplace heats by radiation and by some convection.

The stove heats by radiation, by convection and by conduction.

The efficiency of heating buildings by hot air depends upon convection currents.

The efficiency of steam heating depends largely on convection currents, but radiation and conduction also aid.

In the hot water method of heating, all three ways of heat transference are employed.

Ventilation includes the introduction of fresh air into a building and the removal of foul air.

There are two general methods of ventilation, the gravity system and the forced system.

A fireless cooker is a device into which hot food is placed to cook without the further use of fire.

A vacuum bottle is a device for keeping hot liquids hot and cold liquids cold.

Fact and Thought Questions

1. In what ways is heat transferred?
2. Why do teakettles often have copper bottoms?
3. What substances transfer heat by convection?
4. Explain the hot air method of heating buildings.
5. Explain the steam method of heating buildings.
6. Describe the structure of the hot water system of heating.
7. Describe the plenum system of ventilation.

8. Do all metals when heated expand to the same degree?
9. Describe the vacuum system of ventilation.
10. Compare advantages and disadvantages of (a) stove and furnace heating; (b) hot air and steam heating.
11. Why does a fire "draw" better if the height of the chimney is increased?
12. Why is smoke from a newly kindled fire sometimes driven back into the room instead of going up the chimney?
13. How does a chimney protect health?
14. Why may snow melt from a house roof while the outside temperature is below freezing?
15. How is ventilation related to heat by convection?
16. Why is it better to make stoves of iron than of stone?
17. Describe the vacuum bottle.
18. How does the vacuum bottle prevent the escape of heat?
19. Why are furnaces and furnace pipes often covered with asbestos or other slow-conducting material?

Projects

1. Construct a labeled diagram of a steam heating system.
2. Make a fireless cooker.
3. Study and describe the heating system of your home. Show how it distributes heat, and how it supplies fresh air and moisture. Experiment with the drafts and determine their effects.

Outdoor Observation

Take a walk and record observations on the effects of low temperature in streams and in stone crevices.

Note effects of extreme heat on cement walks, on asphalt and on moist soil.

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CHAPTER IX

WEATHER

There is a good reason why we talk so much about the weather. In no other form do the forces of nature affect us more. Even in this age, when we have harnessed so many of nature's forces to do our bidding, weather still influences our daily actions to a great extent. It is perfectly natural for us to gaze up at the skies in the morning, or at night, so that we may know what weather to expect on the morrow.

Climate, or the customary weather, determines largely where man lives, the kind of house he builds, the clothes he wears, the crops he raises, his occupation, his sports and recreations, and even his disposition.

Weather seems the most changeable thing in this constantly changing earth. No two days anywhere are ever exactly alike. Weather "blows hot" and "blows cold" in the same day. Brilliant sunshine often is quickly followed by cloud, by rain or hail and thunder and lightning. Wind, tempest, and calm alternate. Yet sunlight and cloud, wind and calm, sun warmth and chill air, rain and drought, freezing and thawing, are all governed by settled laws. There is a reason for every change. So weather merits not only our daily interest, but our careful study.

Weather refers to the state of the atmosphere as to temperature, pressure, the quantity of water vapor present, the general appearance of the sky, the direction from which the wind blows, the frost, the dew, the sunshine, the cloudiness, and the amount of rainfall.

The weather determines and influences types of plant and animal life in any locality. No grower of fruits sets orange trees in a section where he knows cold weather will destroy their life, or plants a vineyard where early frosts are sure to injure the grapes. We have learned in our study of geography that some animals thrive in a very warm region and others in a cold region. The supply of sufficient food has always, in all parts of the earth,

influenced and determined the development of a country, and this supply is controlled largely by the weather which prevails there.

You have already studied about two forms of matter which are closely related to the weather. These are air and water. Your knowledge of them should help you to understand some of the causes that produce changes in weather.

Causes of Weather.—The primary cause of weather conditions is the constant change in the amount of heat in the atmosphere. The heat energy which comes from the sun passes off into space in vast amounts and greatly affects both air and moisture. In acting on these it is transformed into the energy of motion and causes rain, wind, tornadoes, hurricanes, waterspouts and similar phenomena. Other causes that modify the weather are the revolution of the earth around the sun, causing the change of seasons; the daily rotation of the earth on its axis, causing day and night alternately; the fact that land and water are not uniformly distributed on the surface of the earth; the variation of the sunlight in different latitudes, and the fact that the atmosphere is subject to changes of pressure as well as of temperature.

Climate.—The climate of any region is the average of its weather conditions over a period of many years. We speak of climate as dry climate, hot desert climate, hot rainy climate, damp ocean climate or changeable climate.

Zones.—The earth's surface is divided into five zones of heat: the torrid zone, which is the hottest; the north and the south temperate zones, which have a moderate temperature; and the north and the south frigid zones, which are the coldest. The differences in the heat of these zones are caused by differences in the angle at which the sun's rays strike the earth. The boundaries between these zones are indicated by parallels of latitude, but their actual limits are not so regular and definite as this seems to indicate; for example, some parts of the frigid zones have as high temperatures as the temperate zones, as in certain sections of Alaska; and some parts of the temperate zones have summer climates that are very hot, as in the very dry sections of southwestern United States.

Causes of Variations.—The causes of variations of climate in the same zone may be due to winds, to the altitude of the regions,

to ocean currents, or to the nearness of large bodies of water. London has a temperate climate, while at Cape Bald, Newfoundland, in the same latitude, it is extremely cold. The warmth of London is due to the warm Gulf Stream that washes the shores of England. In certain parts of western Europe agriculture thrives, due to the same warm ocean currents, while in a similar latitude on the eastern coast of North America plants will not grow, owing to the low temperature caused by the nearness of a cold

THE ZONES OF THE EARTH

ocean current. January temperature in San Francisco averages the same as that of Charleston, South Carolina, which is five degrees of latitude farther south, and the July temperature is the same as that of Halifax, Nova Scotia, which is six degrees farther north. The differences are due largely to the warm winds that blow from the Pacific ocean over the shores of California, and to the warm Japan current which sweeps along her coast.

Temperature of the Atmosphere—Formerly it was believed that the higher we ascend the colder the air becomes. In recent years, through the study of the condition of the upper air, investigators have found that this is not always true. The temperature does continue to fall until a height of about seven miles is reached, but above that there is a belt of slightly warmer air.

The United States Weather Bureau uses balloons in finding out facts about the condition of the air in the upper layers of the atmosphere. A registering balloon is sent up to which is attached an instrument called a *meteorograph* that records, as it rises, the atmospheric pressure, and the rainfall, as well as the temperature and the humidity. Thus the condition of the upper atmosphere is learned.

Precipitation.—Whenever water vapor in the air condenses in drops sufficiently large to fall to the earth, a *precipitation,* or a fall of rain occurs. When the water vapor is frozen as it condenses in the upper atmosphere, we have snow, hail or sleet. If the vapor freezes before much condensation occurs, snow results, forming in beautiful crystals of various shapes. If the raindrops are formed and then freeze into particles of ice in the air, they fall as hail. When snow and rain fall together, we have sleet. The various types of precipitation are *rain, hail* and *snow.*

Hail and Snow.—During thunderstorms raindrops sometimes freeze and form pieces of ice, called hailstones. These pieces of ice fall toward the earth but are often caught by strong upward currents of air and carried up again. When this happens, more snow or water freezes on them, adding a layer of ice. This may happen several times, until the hailstones become heavy enough to fall even against the force of the upward air currents. This accounts for the unusually large hailstones which fall during severe storms, since the more severe the storm the stronger the upward currents of air. Hail storms often do a great amount of damage to crops by cutting the foliage. The windows of houses and greenhouses are sometimes broken by hail.

Snow is formed when the water vapor in the air comes in contact with air at a temperature below 32° F., the freezing point.

In freezing, the vapor crystallizes into many shapes and forms of snowflakes which, under certain conditions, fall to the earth in large quantities and cover it with a white blanket. Although it sometimes fills the highways, making travel difficult, snow also serves some useful ends. In falling, it entangles considerable air which is a poor conductor of heat. Thus the mass of snow protects plants, especially winter wheat crops, from freezing during a cold winter by preventing the escape of heat from the soil. It also gradually melts, filtering into the soil, and in this way feeds springs, thereby aiding in keeping a fairly uniform flow of water in the streams, and conserving the water supply.

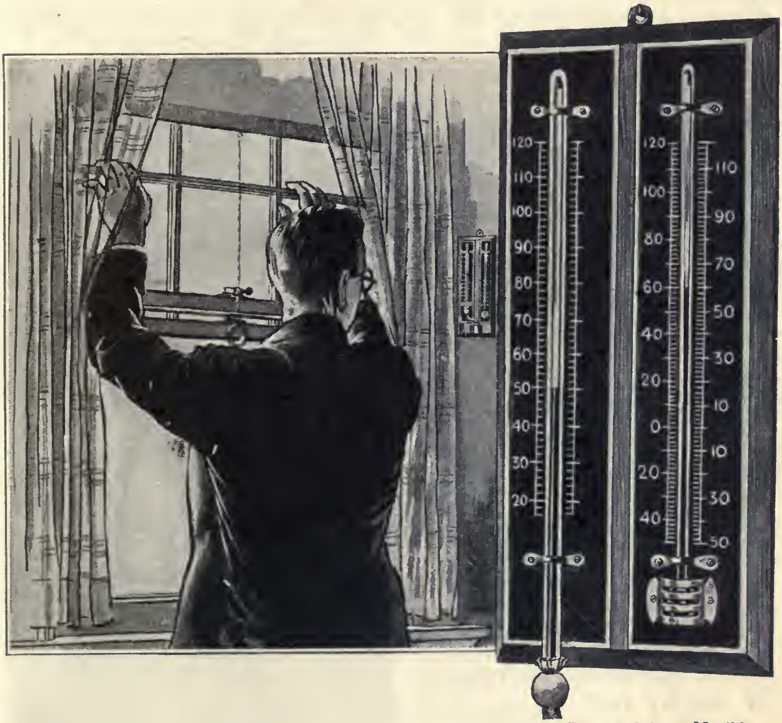
Rainfall.—We commonly think of rainfall as merely the rain that falls; we do not consider the snow. Weather men, however, include snow, hail, and sleet in rainfall, according to the amount of water these will form when melted. In the study of weather, no topic is of greater interest to man than rain, due to the fact that he realizes its great value. If it were not for the rainfall, our streams and lakes would cease to exist, our lands would become deserts and our food supplies would fail.

The atmosphere always contains some water vapor. This is shown by the constant formation of clouds, fog, dew, snow and frost as well as rain. Rain occurs when the water vapor in the air condenses into water particles heavy enough to escape from the clouds and fall to the earth. When air is cooled its capacity to hold moisture is lessened. Vapor, then, condenses when cooled by cold currents of air. These currents reduce the temperature so that the air can no longer hold all of its moisture. The greatest amount of moisture which the air can hold is called the *point of saturation.*

Breathe for a short time on a cold window pane and notice that small drops of moisture appear on the glass. This is caused by the condensation of the water vapor blown from your mouth. In the same manner, on a larger scale, water vapor in the air condenses when it comes in contact with a colder mass of air.

The humidity, or amount of moisture present in the air, affects our bodily health and comfort. If air is too dry, it absorbs mois-

ture from the body too rapidly, producing irritation, especially in the linings of the nose, throat and windpipe, which should always be moist. If the air is too moist the necessary giving off of moisture by the body is checked. We cannot regulate the outdoor humidity, but we can frequently regulate the humidity of the indoor air.



Popular Science Monthly.

USING THE HYGROMETER

Note the difference in degrees shown on the wet and the dry bulb thermometers and find the relative humidity of the room. (See table, page 124.)

From the standpoint of health, the relative humidity, or the ratio of the amount of moisture actually present to the amount the air could hold if fully saturated, should be at least 50 per cent. Relative humidity is determined by means of a *hygrometer* and of a relative humidity table.

One form of the hygrometer consists of a dry bulb thermometer and a wet bulb thermometer. The wet bulb is wrapped with a piece of loosely woven cloth attached to a lamp wick, the lower end of which rests in a cup of water.

RELATIVE HUMIDITY TABLE FOR USE WITH A HYGROMETER

Difference in Degrees between Thermometers	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
Dry Bulb Reading															
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	24
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44

Experiment to Determine the Amount of Water (Relative Humidity) in the Air by the Use of a Hygrometer.—Expose the hygrometer to the air to be tested. Notice the temperature on the dry bulb thermometer. Then notice the number of degrees lower the wet bulb thermometer reads. Then turn to the relative humidity table. Follow across the table on the line giving the reading of the dry bulb thermometer to the column which indicates the number of degrees lower on the wet bulb reading. The figure at this intersection gives the per cent of moisture in the air.

A SIMPLE RAIN GAUGE

If the water in the bottle were spread over an area the size of the top of the funnel, it would give the depth of the rainfall.

Measurement of Rainfall.—Rainfall is measured by a *rain gauge*. This is a device for catching the rain over a certain area

and determining how deep the water would be spread over the area from which it is collected. A simple rain gauge is made by placing a large funnel in a bottle. Collect the water during a rain by placing the gauge out in an unsheltered place. Calculate the depth this water would have if placed in a dish of the same diameter as the top of the funnel. This gives the number of inches of rainfall during the period when the water was caught.

Distribution of Rainfall.—The distribution of rainfall in any country is greatly affected by the surface of the land, and

United States Weather Bureau.

CUMULUS CLOUDS
They often warn of coming thunderstorms.

especially by the presence of mountains. In the western part of the United States, the lowland region east of the Coast Range receives only about 25 per cent as much rainfall in a year as the section on the west side, on account of the high mountains in the range. When the moisture-laden winds coming from the Pacific Ocean reach this range, they are forced upward into a colder region of air. Hence a large percentage of the water vapor condenses and falls on the west side of the mountains.

Sections of land crossed by winds that have already lost most of their moisture are certain to have a desert-like appearance. There is such a region immediately east of the Rocky Mountains.

Among the many maps and charts published by the United States Weather Bureau at Washington, and obtainable at slight cost, are several relating to rainfall, to humidity, and to temperature. The daily weather maps give information on these points

United States Weather Bureau.

TUFTED CIRRUS CLOUDS
The forerunners of a storm.

over periods of twenty-four hours. There is also a special map showing by differently shaded areas the average annual rainfall in all parts of the United States. Other charts deal with other climatic conditions. By studying these maps and charts you can obtain interesting information concerning climatic conditions in your own locality and can learn how these conditions compare with those in other sections.

Dew and Frost.—When there is much water vapor in the air it often condenses and forms drops of water on foliage and other objects. This is *dew.* It is more apt to form on nights when there are no clouds and no wind. You have undoubtedly noticed the drops of water on grass and other plants, or on spider webs, as they glistened in the morning sunlight. They were formed by the condensation of vapor coming in contact with objects which had radiated their heat and become cooler than the air. In

United States Weather Bureau.

STRATUS CLOUDS
Cloud layers that often veil the mountains.

case the temperature of the air near the earth falls to the freezing point, a coating of minute ice crystals forms in place of dew. This is *frost.* Early frost is greatly feared by farmers, since it destroys vegetation and prevents the ripening of crops.

Clouds.—When water vapor condenses in the air near the earth into small drops not heavy enough to fall, it is called

fog, and when it condenses into small droplets high in the air, it forms clouds. *Clouds* are such common things that we should be able to recognize the more important forms. These are known as *cumulus, cirrus, stratus* and *nimbus.*

Cumulus clouds look like heaps of wool in the sky. They appear in the air about 1000 to 2500 feet above the earth and are commonly seen during the middle part of the day and in the afternoon. They are somewhat irregular in shape. When light

United States Weather Bureau.

NIMBUS CLOUDS ABOVE THE FOG

The dark gray clouds that bring the rain.

and fleecy and separated into several small masses, they usually indicate fair weather; but when heavy and marked with rounded tops and large peaks, they are likely to cause showers and are often called thunderheads.

Cirrus clouds have a light feathery appearance and float in the air at a height of from five to ten miles. In the form of plumes with irregular edges, they commonly indicate an approaching

storm, as they are formed by the condensation of moisture in the air currents that precede a storm.

Stratus clouds are dark colored, more or less broken clouds that often appear low in the sky in the early morning or toward evening at a height of from one-fourth to three-fourths of a mile.

Nimbus clouds are the kind that affect us the most, since they actually bring the rain. They are of a dark gray color and have no special form. All storm clouds may properly be called nimbus clouds. They often cover an area of thousands of square miles and appear at various heights, according to the atmospheric conditions. Frequently they are only a few hundred feet above the earth's surface.

SUMMARY

Weather refers to the state of the atmosphere at any given time.

Weather determines in what sections of a country different crops may profitably be grown.

The primary cause of weather is the constant change in the amount of heat in the atmosphere.

The climate of a region is its average weather condition for a long period of time.

There are five zones of heat; two frigid zones, two temperate zones, and one torrid zone.

Rainfall is a topic of great interest to all because our food supplies are dependent on it.

The distribution of rainfall is greatly influenced by the variations in the land surface.

Clouds are caused by the condensation of moisture in the air. The important forms of clouds are the cumulus, the cirrus, the stratus and the nimbus.

Fact and Thought Questions

1. Name several ways in which your habits of life and your occupations differ in summer and in winter.
2. Give several important causes of weather.
3. What is meant by the climate of a region?
4. Which affects our lives more, weather or climate?
5. Name the zones of heat on the earth's surface.

6. Give several causes of the variations of climate in a zone.
7. Why is the rainfall usually greater on the ocean side of a range of mountains than on the opposite side?
8. Is it true or false that there is more danger from frost on a clear night than on a cloudy night? Why?
9. Describe briefly each of four principal kinds of clouds.
10. Explain why clouds sometimes dissolve and disappear without rain.
11. Account for the formation of clouds.
12. What sort of clouds cause you to hasten to shelter?
13. Discuss the benefits of rainfall.
14. What is hail? Snow? Dew? Frost?
15. Why will a shallow flooding of a field protect it against a threatened light frost?
16. Why will frost form on the windows of one heated home in winter and not on those of another?
17. Describe an experiment to illustrate the formation of dew.

Projects

1. Prepare a labeled diagram showing the zones of heat.
2. Construct a rain gauge, and find the amount of rainfall during a shower.
3. Make a weather chart for a week or a month.

Outdoor Observation

1. Read and record outdoor temperatures at your home each morning and night for a week. Compare temperatures at the ground and at second story level.
2. Record your observations of cloud formations for a week, giving character of clouds, direction of drift, and any other facts you discover.

References

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CHAPTER X

WIND AND WEATHER

Wind is a vital part of the weather that influences our daily lives so greatly. It brings to inland areas the moisture that the sun has vaporized from large bodies of water and which here falls as rain to refill streams and to satisfy the thirst of crops and forests and other living things. It refreshes us on hot days. It helps dry the family washing, and pumps the water on many a farm. It drives a host of sailing vessels across ocean and lake. Although we stand in awe of its tremendous force when it whirls in mighty hurricanes that lay waste the land and raise the sea to fury, or, as a tornado, twists along its narrow path of destruction, yet, as a whole, wind is much more man's friend than his enemy.

The pressure of wind on our faces tells us that it is simply air in motion. Motion is a form of energy, so we naturally expect to find the sun, the original source of all energy, responsible for wind. Winds are horizontal movements of the air caused by differences in temperature. The air in great sections of the atmosphere, heated by sun-warmed areas of the earth beneath, becomes lighter and rises, leaving areas of low air pressure. Colder, heavier air from other sections, with higher air pressure, rushes in to replace it. There is a continual tendency of the air to pass from an area of high pressure to an area of low pressure. In this way, winds are caused, their velocity and force depending upon the differences in air pressure of the two areas. As a result we have great movements in the currents of air, governed by laws so well established that weather men can predict with increasing certainty the path and intensity of storms.

This relation of heat to air currents may be illustrated by holding a piece of smoking wood near the draft entrance of a stove. The direction the smoke takes shows that the unwarmed air of the room is passing into the draft entrance to take the place of the air that has become heated and is rising.

Secondary Causes of Wind.—The revolution of the earth around the sun causes a great variation in the amount of heat received in the different seasons on certain portions of the surface of the earth. This necessarily affects the movements of air currents. The boundaries of wind belts vary with the seasons. The daily rotation of the earth on its axis, although it does not cause the winds to blow, does modify the direction of their paths. The unequal distribution of land and water on the earth's surface also affects the winds, since water gives off its heat into the atmosphere less rapidly than land does.

The Belt of Calms.—There is an irregular section of the earth in the torrid zone, known as the *heat equator* or *belt of equatorial calms.* This belt does not always cover exactly the same area but shifts several degrees north or south with the change of seasons, due to the inclination of the earth's axis in its motion around the sun.

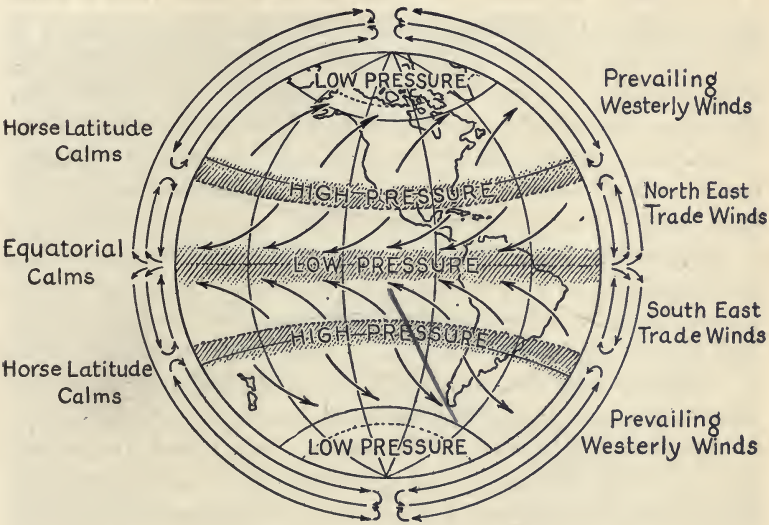
This belt of calms receives a vast amount of heat from the sun. The air over its heated land and water surfaces becomes hot, grows light, and rises, its place being taken by air flowing in from both north and south. The air pressure is low because the air is warmer and hence lighter than either north or south of this region, due to the direct and hottest rays of the sun. The air appears generally calm because of its movements upward in immense masses. Rains are frequent, since the rising air is cooled on reaching higher levels and cannot hold its moisture.

The Anti-Trade Winds.—The immense masses of air rising from the belt of equatorial calms to higher levels flow north or south, gradually shifting to an easterly direction and forming what are called the *anti-trade winds.* A part of these air masses settles to the earth in the neighborhood of the tropics of Cancer and Capricorn, causing the horse latitude calms, or belts of tropical calms. The portion of the anti-trade winds which does not settle at the horse latitudes continues toward the poles.

Horse latitude calms are high pressure areas of cool, dry air which has settled to the earth. In taking up heat again from the earth's surface this air absorbs considerable moisture, drying up

the land. This accounts for the fact that most of the great deserts of the world, such as the Desert of Gobi in Asia and the Desert of Sahara in Africa, lie in these calm areas.

The Trade Winds.—From the high pressure areas of the horse latitudes some of the descending air flows toward the equator and some toward the poles—areas of low pressure. From the northern tropical belt of calms air flows in a southwesterly direction toward the heat equator. From the southern



The Winds of the World

Which arrows on the globe indicate the trade winds? The prevailing westerlies? Trace, on the lines outside of the hemisphere, the course of the anti-trade winds, the trade winds, the polar drift, and the westerlies.

tropical belt air flows in a northwesterly direction toward the heat equator. In each case the air currents are turned from the north and south line toward the west by the rotation of the earth.

These two wind currents are called the *trade winds* because vessels engaged in trade formerly depended on them for motive power. The northern trade winds brought Columbus to America and terrified his sailors because they could not understand how they could ever return against them.

Prevailing Westerlies.—The air masses settling to the earth at the horse latitudes are made up of the anti-trade winds and also of air masses drifting at high levels toward the equator from the poles. On approaching the earth the part of the descending air masses which does not flow to the equator as trade winds flows toward the poles and is called the *westerlies*. The westerlies flow over a large portion of both temperate and frigid zones. North of the equator they are turned from a northward path to a northeasterly direction, and south of the equator from a southward path to a southeasterly direction, due to the rotation of the earth. The climate in the regions over which the prevailing westerlies blow is variable. In these regions are the greatest crop producing countries and the most highly developed civilization.

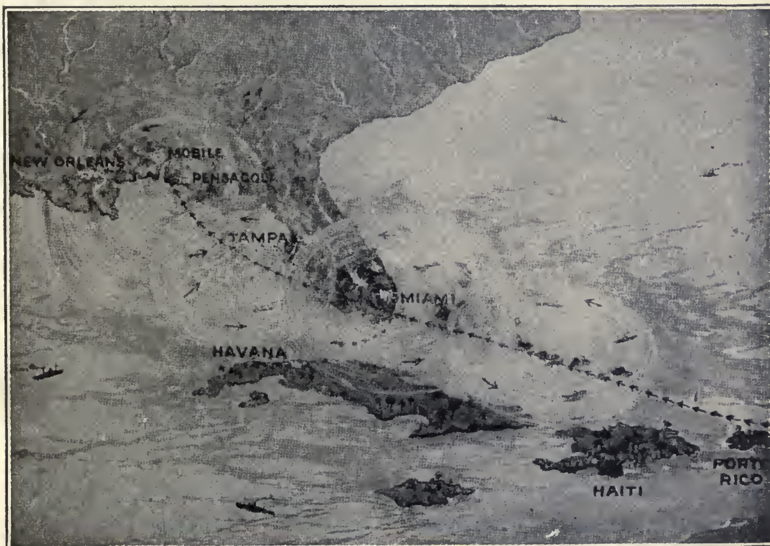
In the polar regions the westerlies are drawn by the earth's motion into great whirls of air, forming areas of low pressure. Here the air rises and then turns back toward the horse latitudes.

Storms and Local Winds.—The storm conditions and rapid variations of local weather which we experience are largely due to eddies or whirls in these great air currents of the world, caused by such local conditions as mountain ranges and the uneven heating of sections of land and water. These include cyclones, hurricanes, thunderstorms, tornadoes, waterspouts and land and sea breezes.

Cyclones or Lows.—Winds blow from all directions toward an area of low pressure. The revolution of the earth gives such winds a whirling motion. The direction of this whirl in the northern part of the earth is opposite that of the hands of a clock, and in the southern part the same as that of the hands of a clock. These low pressure areas, or *lows,* are very small as compared to the belt of calms, although they may be a thousand miles in diameter. They are caused by unequal heating of the land surface. The whirl of the air around these low pressure areas is called a *cyclone*. These cyclones move along with the westerly winds and as they pass they change the direction of local winds. That accounts for a north wind one day and a south wind another. We commonly read of cyclones occurring in certain localities and tearing down buildings or rooting up trees. Such storms are not properly called cyclones. They are *tornadoes*.

A winter cyclone that originates in the northern Pacific waters moves across the United States at a rate of about 800 miles a day. If it originates in the southern Pacific waters, and takes a northeasterly direction over the country, it often moves more rapidly. In summer, the rate of movement is less.

An *anti-cyclone* is an area of high pressure, frequently traveling in the wake of a cyclone. The winds blow away from its center instead of toward it. Its center is a place of clear sky



Popular Mechanics Magazine.

THE GREAT HURRICANE OF OCTOBER, 1926

Forming over the warm waters south of the West Indies, it whirled across Florida, leaving death and destruction in its path.

which carries fair weather with it. Because the air at the center is cold and heavy, it settles, bringing us in winter cold waves of clear weather soon after a cyclone has passed.

The United States Weather Bureau summarizes wind and barometer indications as follows: "When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or the northwest, and its center will pass near or north of the observer

within 12 or 24 hours with wind shifting to the northwest by way of southwest and west. When the wind sets in from points between east and northeast, and the barometer falls steadily, a storm is approaching from the south or southwest and its center will pass near, or to south or east of the observer within 12 to 24 hours with the wind shifting to the northwest by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and amount of the fall in the barometer."

Hurricanes.—Certain types of storms of an exceedingly violent nature develop over the ocean in the region of the belt of calms in the tropical latitudes. They blow at a rate of from 80 to over 100 miles an hour. Although the effects of their passage may be felt over a belt 1000 miles wide, violent winds are usually limited to a belt of about 250 miles in width. They are accompanied by heavy rainfall and are often very destructive to shipping and other interests, sometimes laying waste cities near the ocean. Such storms in the Atlantic Ocean are known as *hurricanes* and in the Pacific Ocean as *typhoons.* In their progress they take a curved path toward the northwest, gradually changing to a northeast direction as they enter the temperate zone.

Thunderstorms.—A thunderstorm is any storm accompanied by thunder. Thunderstorms commonly come after a spell of hot weather. The hot, moist air, being lighter than the surrounding colder air, rises, and the colder air takes its place. As the air rises, the moisture in it condenses and forms clouds which become charged with electricity, which passes from cloud to cloud or from the clouds to the earth in the form of lightning. Thunder is caused by the vibration that occurs in the air as the electricity passes through it. In the passage of lightning through the air, much of its energy is transformed into heat and often when it strikes an object, such as a building, fire results. Many serious forest fires are caused by lightning striking dead timber.

Thunderstorms may be either general or local. They are usually accompanied by heavy rainfall and sometimes by hail.

Tornadoes and Waterspouts.—Tornadoes are quite similar to hurricanes, except that they cover a much smaller area and are of shorter duration. A tornado has the same whirling motion

of the air as a cyclone. Although the size of the whirl is small, the inflow of the wind is terrific, and often great damage to buildings and other property occurs in its course. A tornado seldom extends over forty miles in the length of its course, and its width rarely exceeds a quarter of a mile. It usually travels in a northeasterly direction.

Brown Brothers.

A Tornado. Wind in Its Most Violent Form

Suggest a reason why the men do not seek shelter.

When a tornado develops in the ocean, or other body of water, a funnel-shaped water column, called a *waterspout,* is sometimes formed. This appears to connect the clouds above with the water below. It is believed that most of the water which forms the spout is condensed from the water vapor of the air itself.

Land and Sea Breezes.—Land and sea breezes are due to the fact that the land warms faster than the water in the daytime and cools faster than the water at night. As the air above the land warms in the daytime, it becomes lighter and rises, and cooler air from the water area flows in to take its place, thus causing a sea breeze. Again, as the air above the land in the evening becomes cooler, it flows over the water to take the place of warmer air that is rising, thus causing a land breeze.

Underwood & Underwood.

In the Wake of a Tornado

Weather Instruments.—In addition to the thermometer, the barometer, and the rain gauge, there are other instruments used in the study of the weather. Among these are the *aneroid barometer,* the *barograph,* and the *anemometer.*

An aneroid barometer is a non-liquid barometer and resembles an ordinary alarm clock in form. Like all barometers, it indicates the pressure of the atmosphere and is therefore useful in foretelling the weather. It has a dial upon its face with two pointers.

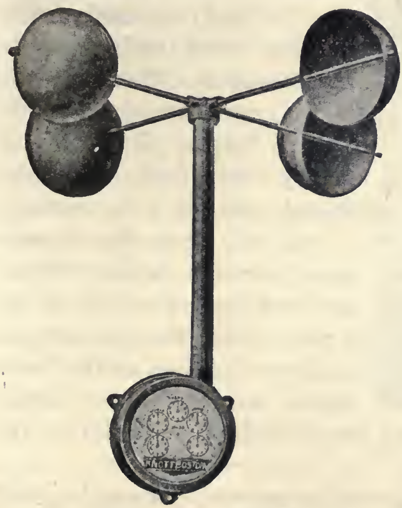
One indicates the air pressure, the other may be set at any reading. The difference in the readings of the two pointers shows the change in air pressure. Within the outer casing is a metal box from which nearly all the air has been removed. The top of the box is flexible, and is connected to one of the pointers by means of a series of levers and wheels. When the atmospheric pressure increases or decreases, the top curves slightly inward or outward accordingly. These movements affect the system of levers and wheels and cause the pointer on the face of the dial to indicate the air pressure in "inches and fractions thereof."

L. E. Knott Apparatus Co.

The Aneroid Barometer

It records the pressure of the atmosphere and predicts the weather.

The barograph is made on the same principle as the aneroid barometer. It is a self-recording instrument, having mechanism so arranged as to indicate the record of the air pressure on a chart attached to a cylinder which rotates by means of clock work.



The Anemometer

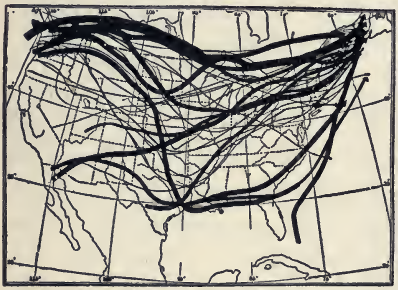
It measures the force of the wind.

The anemometer is an instrument used to measure the force of the wind. It consists of four cups so arranged on an axis that they revolve when the wind strikes them. Revolutions are recorded on a dial so set up that five hundred revolutions per hour indicate one mile velocity of wind.

Paths of Storms Across the United States.—In considering the storms of any section, it should be borne in mind that land heats in the sun's rays more rapidly than

water but retains the heat for a shorter time. Hence, with the coming of summer, the land area of the United States, being in a northern continent, becomes much more heated than the waters bordering it. On this account, low pressure develops over the country and, as a result, winds blow more or less inland. This causes prevailing southerly winds which bring hot waves.

On the other hand, with the coming of winter, the large bodies of water that wash the shores of the country retain their heat much longer than the land areas. High pressure develops over the land areas and causes winds to blow seaward. As a result, west and northwest winds blow over the greater part of the United States east of the Rocky Mountains and bring cold waves.



U. S. Weather Bureau.

PATHS OF STORMS ACROSS THE UNITED STATES

Notice how these storms tend toward the St. Lawrence valley.

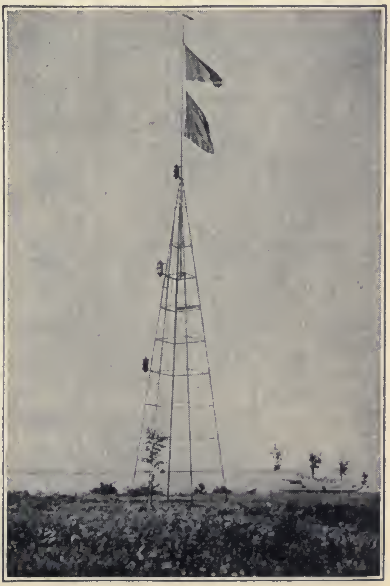
Most of the cyclonic storms that occur in the United States start over the waters of the Pacific, northwest of the country. The weather maps show that they come into the United States near the northwestern boundary. They usually blow over the land in a southeasterly direction until they pass the middle section. Then they turn to the northeast, leaving the country by the St. Lawrence valley. Sometimes the storms, as they come from the Rocky Mountain system, veer to the south and even reach the coast of the gulf of Mexico. These also commonly leave the country in a northeasterly direction, passing out over the Atlantic Ocean. Weather maps indicate that some cyclones start in waters off the southwest coast of the country and pass over it through Arizona and New Mexico, then taking the same direction as the other storms. The movements of all cyclonic storms seem to follow in a general way the course of the prevailing westerlies of the middle latitudes.

Weather Lore.—Although weather science, commonly called *meteorology,* is a new science not yet a century old, men for

thousands of years past have been interested in weather and have made observations about it. Many of these have come down to us in the form of sayings and proverbs, known as *weather lore*. The following are a few examples:

> "If hoar frost comes on mornings twain,
> The third day surely will have rain."
>
> "If the sun goes pale to bed,
> 'Twill rain tomorrow, it is said."
>
> "Evening red and morning gray
> Will help the traveler on his way."

Some people, not scientists, try to foretell the weather by observations of the sky and the clouds. For example, a rainbow in the afternoon means fair weather. If the sun before setting is a brilliant white, it foretells a storm. A red sky in the morning means rain. There are many other such observations. This method, however, is not that of the weather science man. He bases his predictions on more scientific observations.



STORM-WARNING TOWER
Flags by day and lanterns by night foretell the weather.

The Weather Bureau.—The United States Department of Agriculture maintains a Weather Bureau that predicts in a scientific way the coming weather. All over the country there are stations for the observation of weather conditions. Here men observe daily the temperature, the air pressure, the direction of the wind and the amount of moisture in the air. They telegraph the results of their observations to Washington, D. C., where the reports from all the sections are studied and predictions made accordingly. These predictions are

Districts and Stations	Barometer readings, in inches	Temperature	Wind direction and velocity, in miles per hour	Sky and precipitation
Atlantic Coast				
Boston	30.46	34	S. E. 12	cloudy
Albany	30.34	32	S. E. 20	"
New York	30.32	38	E. 34	"
Philadelphia	30.24	40	S. E. 14	rain
Washington	30.16	36	N. Lt.	"
Lynchburg	30.12	36	N. E. Lt.	"
Norfolk	30.12	42	N. Lt.	"
Jacksonville	30.12	66	S. 8	clear
Tampa	30.14	68	S. E. 12	cloudy
Gulf States				
Atlanta	30.02	50	N. E. 6	rain
Mobile	30.06	70	S.W. Lt.	fair
Montgomery	29.98	70	S. 12	cloudy
Vicksburg	30.08	62	N.W. 12	fair
New Orleans	30.06	70	S.W. 6	"
Shreveport	30.14	54	N.W. 8	clear
Fort Smith	30.16	38	W. 12	"
Little Rock	30.06	48	W. 12	fair
Galveston	30.06	66	N.W. 6	cloudy
Palestine	30.18	52	N. E. 6	"
San Antonio	30.04	62	N. 14	"
Fort Worth	30.24	42	N. 8	fair
Ohio Valley and Tennessee				
Indianapolis	29.64	56	S.W. 28	clear
Pittsburgh	29.88	42	S. 6	rain
Cincinnati	29.74	58	S. 14	cloudy
Columbus	29.72	54	S. 12	"
Louisville	29.76	58	S. 14	"
Chattanooga	29.98	50	S. E. Lt.	rain
Memphis	30.02	56	W. 14	fair
Nashville	29.92	60	W. 8	cloudy
Parkersburg	29.82	50	S. E. 14	"
Lake Region				
Chicago	29.54	40	S.W. 36	cloudy
Detroit	29.64	42	S. 10	"
Grand Haven	29.50	40	S. 12	"
Marquette	29.68	24	W. 12	snow
Sault Ste. Marie	29.62	24	E. 14	"
Duluth	29.90	26	N.W. 18	"
Cleveland	29.68	48	S. E. 30	rain
Buffalo	29.78	40	S. 18	cloudy
Parry Sound	29.74	28	S. E. 36	"
White River	29.80	18	N. Lt.	snow

Districts and Stations	Barometer readings, in inches	Temperature	Wind direction and velocity, in miles per hour	Sky and precipitation
Upper Mississippi Valley				
Cairo	29.88	54	W. 20	clear
St. Louis	29.84	40	W. 28	cloudy
Springfield, Ill.	29.74	38	W. 20	"
Keokuk	29.84	36	W. 26	"
Davenport	29.62	34	W. 16	rain
Des Moines	29.96	28	N.W. 20	cloudy
Dubuque	29.64	32	N.W. 20	snow
St. Paul	29.88	24	N.W. 16	fair
Missouri Val.				
Kansas City	30.08	32	N.W. 12	cloudy
Springfield, Mo.	30.10	28	N.W. 26	clear
Concordia	30.30	30	N.W. 24	"
Omaha	30.10	24	N.W. 16	cloudy
Sioux City	30.12	18	N.W. 28	"
Huron	30.20	10	N.W. 30	"
Bismarck	30.58	— 4	N.W. 8	clear
Moorhead	30.30	8	N.W. 20	cloudy
Northwest Territory				
Calgary	30.62	—16	0	clear
Minnedosa	30.70	—12	S.W. Lt.	"
Prince Albert	30.68	—32	0	fair
Swift Current	30.72	—12	0	cloudy
Qu'Appelle	30.64	— 6	Lt.	"
Rocky Mountain Slopes				
Havre	30.42	zero	N. E. 8	clear
Helena	30.40	2	W. Lt.	snow
Miles City	30.50	2	N. Lt.	fair
Rapid City	30.50	4	N. E. 6	"
Valentine	30.48	4	N.W. 12	clear
North Platte	30.48	8	N.W. 14	"
Cheyenne	30.46	8	S. 8	"
Lander	30.36	4	S.W. Lt.	cloudy
Salt Lake City	30.00	40	S. E. 6	"
Denver	30.38	14	N. E. 18	clear
Pueblo	30.30	18	E. Lt.	fair
Sante Fé	30.18	24	0	clear
El Paso	30.14	30	N. E. Lt.	"
Abilene	30.26	36	N. 6	"
Amarillo	30.30	22	N. 14	"
Oklahoma	30.24	30	N. 14	"
Dodge City	30.38	18	N.W. 12	"
Wichita	30.30	24	N.W. 14	"
Grand Junction	30.14	32	E. 20	cloudy

Weather Observations Taken at 8 A. M., 75th Meridian Time

From this table, estimate as nearly as possible what weather prevailed in your neighborhood.

sent to all sections of the country, usually at regular periods and in time to give full warning of storm or cold.

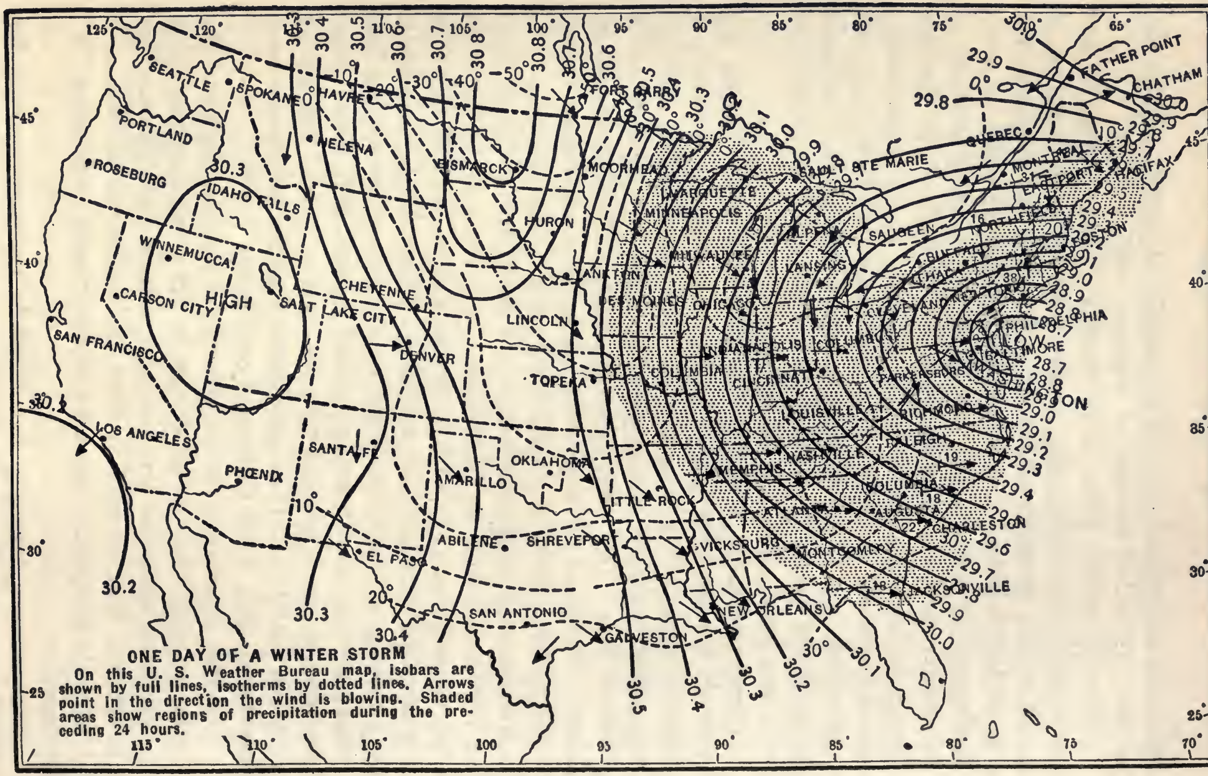
In many leading cities, daily weather maps are prepared and are widely distributed, thus giving the public information in regard to the probable course of storms and the prospects for good or bad weather. Condensed reports also are given by newspapers and by radio. The saving to the business interests of the country every year brought about by the work of the Weather Bureau is large and justifies the expense of its maintenance. Among the kinds of bulletins sent out are warnings to ships and shipping interests of approaching storms, to railroads and shippers of perishable goods of coming cold waves, and to growers of fruits and garden products of probable frosts.

Construction of Weather Graphs and Maps.—Anyone can construct a weather graph if he has the data. It is merely a graph showing the variation of a weather condition, such as atmospheric pressure, temperature, or inches of rainfall, for a period of time. To obtain this data, make daily observations of weather conditions for a given length of time and keep a record of them. Then make a graph, based on the records kept.

To construct weather maps, secure blank weather maps from the Weather Bureau at Washington, D. C., and fill in the maps from the table on page 142, or similar data. This will help you to understand weather maps and many things about the weather. By reference to the table, draw on the map a connecting line through all places with a temperature marked 50°. Draw other lines through places marked 40°, 30°, and so forth. These lines are called *isotherms*. They pass through places having the same temperature at a fixed time on a certain date.

On the same map, wind directions may be indicated by arrows pointing with the wind; that is, for a wind coming from the southwest make the arrow point toward the northeast. Certain symbols may be used to show the weather conditions, as a white circle for fair, a black circle for cloudy, or a letter "R" for rain.

The pressure data may be plotted in the same manner for the different places on the map. You know that air has weight



ONE DAY OF A WINTER STORM

On this U. S. Weather Bureau map, isobars are shown by full lines, isotherms by dotted lines. Arrows point in the direction the wind is blowing. Shaded areas show regions of precipitation during the preceding 24 hours.

and rests on the earth with a pressure averaging nearly 15 pounds per square inch, and that such pressure varies in different parts of the country at any given time. After indicating the pressure data or barometric readings on the map, draw a line with a colored pencil connecting all places having a barometric reading of 30 inches. Draw another line through places with a barometric reading of 30.1 inches, and similar lines for each tenth of an inch variation. These lines are called *isobars;* they pass through places where the pressure or barometric reading is the same at a given time on a given date. Write the word "Low" where you find the lowest pressure reading and the word "High" where you find the highest.

The main cause of changes in weather in our latitudes is the movement across the continent of cyclones (lows) and anti-cyclones (highs). The Weather Bureau finds out the directions and the rates of motion of these cyclones and thus is able to forecast quite accurately the weather conditions of all places over which they are expected to pass. Since the growth and the harvesting of farm crops, the success of many industries and occupations, and even the health of people depend to a large extent on the weather conditions, the importance of the work of the Weather Bureau is apparent.

Climatic Regions.—Although the United States lies in the temperate zone, there is considerable difference in the climate of the various sections. In a general way it may be divided into several climatic regions but, even in these, local causes often bring sudden changes of weather. It is difficult to find a place where a perfectly satisfactory climate prevails the year round, that is, a climate which is always best for the health and comfort of those who live there. In seeking a satisfactory climate, it is necessary to consider the average temperature, the relative humidity, and the changes which occur in both temperature and humidity, the nature and changes of the prevailing winds, the amount of sunshine and of cloudy weather, the amount of rainfall and times of year when it occurs, the altitude of the section, and whether the atmosphere is free from dust and other undesirable matter. It seems hardly possible to find a place where all these

conditions are ideal. Hence it becomes necessary for persons whose health requires the best conditions to live in one section for a part of the year and in another section for another part of the year. Accordingly, many live in Florida or California or in some other warm region in the winter and in a cooler region in summer.

SUMMARY

Winds are movements of the air caused by differences in the temperature of the earth.

Winds are affected by the revolution of the earth around the sun. The daily rotation of the earth also modifies the direction of their flow.

The belt of calms, known as the heat equator, is an almost windless section of the earth in the torrid zone. It varies with the seasons.

The trade winds are constant movements of the air blowing southwest in the northern hemisphere and northwest in the southern hemisphere. Anti-trade winds flow in an opposite direction to the trade winds and above them.

Westerlies are air currents that flow from west to east over large portions of the temperate zones.

Cyclones are winds that have a whirling motion. They come from regions of low pressure.

Hurricanes and tornadoes are violent forms of cyclones.

Important weather instruments are the barometer, thermometer, aneroid barometer, barograph, and anemometer.

The paths of storms across the United States follow certain fairly well defined courses.

The United States Weather Bureau foretells the nature of weather and issues bulletins concerning it.

There are marked differences in the climate of various parts of the temperate zone in the United States due to local causes.

Fact and Thought Questions

1. Mention several helpful effects of wind you have personally noticed; several destructive effects.
2. Give the primary cause of wind.

3. State the effect of the rotation of the earth on the direction the wind blows in the northern hemisphere.
4. Describe the belt of equatorial calms.
5. State the location and the course of the trade winds; the anti-trade winds.
6. Describe the origin and benefits of the prevailing westerlies.
7. Describe the origin of cyclones.
8. Account for the formation of land breezes; of sea breezes.
9. Describe an aneroid barometer.
10. Does the arrowhead of a weather vane point in the direction of the wind, or against it?
11. How would a lack of wind affect our lives?
12. Suggest some possible causes of whirls and gusts of wind close to the ground.
13. Why is a window sometimes blown out instead of in during a heavy wind?
14. Why is it dangerous for an airplane to fly close to mountain cliffs?
15. Mention several benefits to the country as a result of the work of the Weather Bureau.
16. Give the conditions of an ideal climate.
17. How is it that sometimes two clouds are seen drifting in different directions?
18. What is a northwesterly wind?

Projects

1. Construct a local weather chart based on personal observations.
2. Make a weather map and explain it.
3. Construct a weather vane and show how it works.

Outdoor Observation

1. Send up several toy balloons under different weather conditions and record observations of drifts and heights reached.
2. Observe a weather vane at regular intervals for a week and record wind directions. Record cloud or storm conditions at the same times.
3. Observe and record visible effects of wind.

References

Whirlwinds and Cyclones..*Davis*
Reading the Weather..*Longstreth*

CHAPTER XI

THE HEAVENS

On a clear night, when the stars are bright in the heavens, it is easy to understand how the men of old looked up at the skies with wonder. Lacking scientific knowledge, they came to believe that the stars had power to influence their lives. Imagination led them to see gods and heroes and animals outlined in stars.

We of today, aided by what the science of astronomy tells us, have even stronger reason than the ancients to be awed by the Universe beyond our world. True, we know now that the stars have little effect upon us. The small portion of the sun's energy which comes to the earth means more to our lives than all the influence of the countless other star-suns that dot the heavens. Our imaginations cannot grasp the vast unthinkable spaces of the sky, the enormous size of the stars far out in space and the perfect law and order that govern all.

We sometimes think that the range of our sight is only a few miles long at best. When we gaze at the sun, however, we are seeing an object 93 million miles distant. When we look at the nearest fixed star we gaze millions of millions of miles beyond the sun. We hardly have words with which to express these distances. We cannot begin to appreciate the vastness of space.

The study of the heavens will repay the time we give to it, especially the study of the sun and its group of planets, of which our earth is one. Our knowledge of our surroundings would be utterly inadequate unless we tied it up with the source of all our energy—the sun—and so linked ourselves and our earth with the entire Universe.

The Heavens is a very inclusive term. It not only includes the *solar system* but also the *sidereal,* or starry, system. The vast dome of the sky filled with brilliant stars is one of the most beautiful sights ever seen by human eye. It is impossible for the mind to comprehend its extent.

The Sun and His Family

The study of the skies, which deals with all the heavenly bodies, we call astronomy. Every bit of knowledge that astronomy has gathered and classified concerning the heavens is highly interesting, but it is necessary for us to limit our study to the sun, the earth and its moon, and to a few of the stars and *constellations,* or groups of stars.

The Solar System.—The solar system consists of the sun and the bodies which revolve around it. The largest of these are called the major planets. They are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. Most of these, in their turn, have satellites, or moons, which revolve around them. In addition to the major planets, there are over 250 minor or lesser planets, numerous meteors, or shooting stars, and a number of comets, consisting of bright heads and long luminous tails.

The Sun.—The sun is the center of the solar system and is its largest member. Its diameter is estimated to be 866,000 miles, which is over 100 times the diameter of the earth. Its volume is 1,300,000 times that of the earth, and its weight is so great that it can be expressed in tons only by a number made up of twenty-eight figures. Its power of attraction is so strong that it overcomes the centrifugal force, or tendency of the revolving planets and other bodies of its system to fly off on straight lines, and compels them to revolve about it. The path of the earth around the sun is not a perfect circle but an ellipse—an oval-shaped curve having greater length than width. Because of this, the distance from the earth to the sun is not always the same.

Composition.—There are various theories in regard to the composition of the sun. One theory, Wilson's, assumes that the sun consists of a solid dark globe surrounded by three atmospheres. The atmosphere nearest the dark center is a dense, cloudy substance having great reflecting power. The middle atmosphere is made up of a vast quantity of glowing gas from which light and heat radiate. It is called the *photosphere* and is the part that is visible to us. The outer atmosphere is quite similar to our atmosphere and is transparent.

The Kirchoff theory, the one now generally accepted, supposes there are four different parts of the sun, arranged as follows:

the *nucleus,* or center, consisting of gas in a highly condensed condition; the *photosphere,* a covering of burning gas several thousand miles thick, the visible part of the sun; the *chromosphere,* made up of luminous gas, mostly hydrogen; and the *corona,* a halo of pale light around the sun. The corona is never visible except during a total eclipse when the sun itself is hidden from our view by the moon. During a total eclipse the corona appears as ribbon-like bands reaching out at times several thousand miles. Of these four parts of the sun, only the photosphere is usually seen by the eye and the telescope; the other parts may be seen during an eclipse, or can be studied by the aid of an instrument called the spectroscope.

Brown Brothers.

FLAMES OF THE SUN

Streamers of fire 75,000 miles in length

Function.—The function of the sun is to provide radiant energy, that is, heat and light. It is the ultimate source of most of the energy in the solar system. Heat and light waves go out from the sun into space equally in every direction.

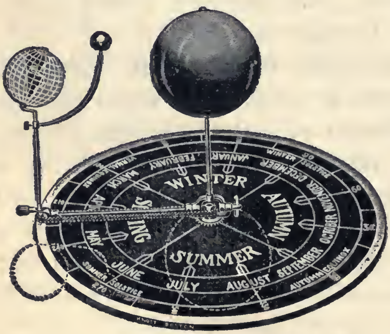
The Earth.—Our earth is naturally the planet in which we are most interested. Its diameter is about 8,000 miles and its volume is far less than one-millionth of that of the sun, around which, like all other planets, it revolves. The time taken by a planet to cover its path, or *orbit,* around the sun is its year. No two planets have the same length of year. Our earth requires a year of 365¼ days to make a revolution. Hence we call our regular calendar year 365 days, adding one day every fourth year, or leap year.

Experiment to Show the Motions of the Earth and Its Moon in Their Orbits, and Their Relation to the Sun.—Use a board 15 inches wide and 24 inches long with holes bored along the line of an ellipse, a small globe mounted on a stick that fits into the holes, and a lighted candle. The ellipse represents the orbit of the earth around the sun, the globe represents the earth, and

the lighted candle represents the sun. Place the candle on the board a little to the right of the center of the long axis of the ellipse. Locate the point at the extreme left of the long axis of the ellipse. Call this point A. Locate the point at the extreme right of the long axis. Call this point C. Locate the two points on the ellipse halfway between A and C. With A at your left, call the point nearest you B, and the opposite one D.

Place the globe at A. At A the axis of the globe should point along the long axis of the ellipse with the top toward the center of the ellipse. When the globe is at A, it represents the position of the earth with reference to the sun on June 21 of each year, and the season is summer north of the equator. Now move the globe along the line of the ellipse to the point B, never changing the direction of the axis of the globe. This represents the position of the earth on September 22 of each year, and the season is autumn north of the equator. Next move the globe to C. The earth is in this position with reference to the sun on December 22. The season is winter north of the equator, and the earth has traveled through one-half of its orbit. Placing the globe at D shows the earth's position on each March 21, and it is spring north of the equator. When the globe has traveled back to A it has made a complete revolution around the light which represents the sun. This shows the yearly motion of the earth in its orbit.

While the earth is traveling around the sun once each year, the moon is traveling around the earth once in about each 29½ days. Since the moon's orbit circles the earth, it is clear that the moon also journeys around the sun once in each year.



L. E. Knott Apparatus Co.

Apparatus to Show Relative Movements of the Earth and the Moon Around the Sun

The apparatus illustrated above shows the motions of the earth and the moon around the sun. As the globe, which repre-

sents the earth, is moved about its orbit, a small ball representing the moon revolves about the earth.

Make a drawing showing the path of the earth and locating the sun. With the earth in some one position draw the orbit or path of the moon. Label the ellipse to show the position of the earth at the different seasons of the year.

The effects of change of seasons on plants, animals and people are apparent. At the approach of winter, plants cease to grow and many lose their foliage; many birds *migrate,* moving to warmer regions; some animals, like the bear and the woodchuck, *hibernate,* or go to sleep for the winter; and many people move to lands where summer climate prevails. As spring and summer return, the birds reappear, and the hibernating animals come from their holes or dens.

Brown Brothers.

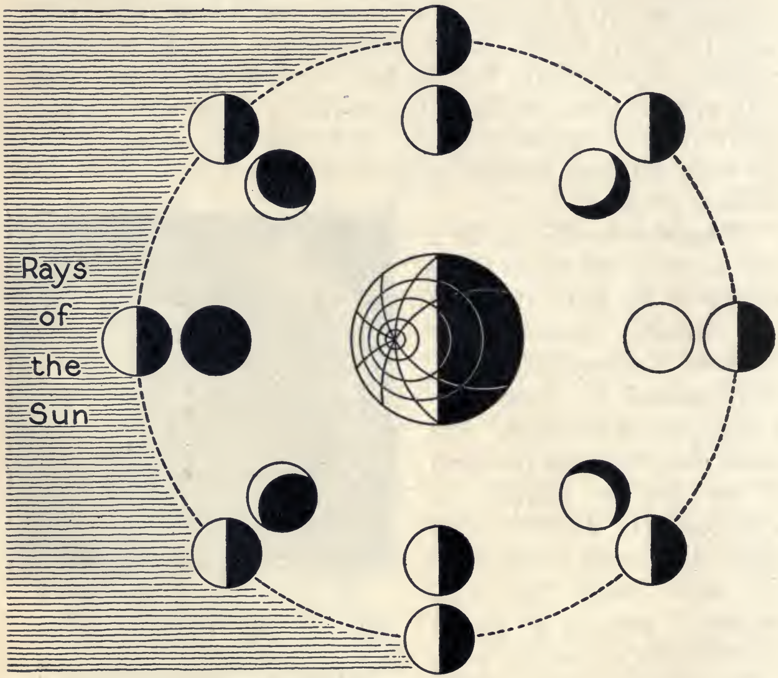
THE FULL MOON

The Moon.—Except for a few meteors, the moon is the nearest to the earth of any of the heavenly bodies. Her diameter is about 2,160 miles. Her volume is about one-fiftieth that of the earth. The moon revolves about the earth at an average distance of approximately 240,000 miles. Since the moon's rotation on her axis takes the same amount of time as her period of revolution around the earth, she always turns the same portion of her surface to the earth. Nearly half her surface is never seen from the earth.

Phases of the Moon.—In the moon's revolution around the earth, she shows herself to us in constantly changing forms. These changing forms, sometimes full moon, sometimes half-moon, and sometimes a mere crescent, are called the *phases* of the moon. These phases are caused by the changes in the relative position of the sun, moon, and earth, and the varying portions of the moon's surface that can be seen from the earth. The moon

is a dark body without an atmosphere to support life. It shines by reflecting the light from another body, the sun.

First the moon is seen as a small crescent in the western sky just after sunset. This occurs a day or two after new moon, at which stage the moon is too near the sun to be visible. The horns, or cusps, are turned to the left, that is, to the east. Each



PHASES OF THE MOON

The outer circle shows the moon in relation to earth and sun. The inner circle shows it as it appears to us.

succeeding night for several nights the crescent appears larger and brighter and the times of setting become later, until half of the lighted hemisphere is visible to us. The moon is now in her first quarter. The moon moves along toward the east in her orbit until about the fifteenth day after new moon when she arrives at a point in the heavens exactly opposite to the sun. We now

see the whole of the lighted part and we have a full moon, which shines brilliantly all night. The moon's revolution up to this point is often referred to as the *waxing* of the moon. The period from half moon to full moon is known as the second quarter.

The moon, continuing in her course around the earth, now shows phases in a reverse order from those in the second quarter. The part of the lighted side visible to us grows less night by night until after about seven days she again resembles a half circle, and half of the lighted hemisphere is again visible to us. This period from full moon to half moon is known as the third quarter.

The visible portion continues to decrease until only a crescent is seen with the cusps pointed toward the west. Finally the lighted side is wholly invisible to us, and a complete revolution has been made. This period from half moon to new moon is known as the fourth quarter. The last half of the revolution is often referred to as the *waning* of the moon. The period of time in passing through one revolution from new moon to new moon is about 29½ days. This period constitutes a lunar, or moon, month.

The Tides.—Among the interesting sights at the seashore are the rise and fall of the ocean level at regular intervals. These regular movements of the ocean are called *tides.* A rising tide is called a *flood* tide and a falling tide is called an *ebb* tide.

Tides are caused by the attraction, or pulling force, exerted by the sun and by the moon. Since this attraction lessens rapidly as distance increases, the nearby moon exerts far more pull than the greater, but far distant, sun. If the moon stood still, we would have a high tide and a low tide every 12 hours, but, owing to the changing position of the moon with relation to the earth, the tide rises for 6 hours, 13 minutes and then falls for the same period, causing a high tide every 12 hours, 26 minutes.

When moon and sun are in a position to exert their attracting forces at the same point or at opposite points on the earth, we have extreme high tides, or *spring* tides. When the attractive forces of sun and moon act at right angles, we have low, or *neap,* tides.

High tides are of value in deepening the water over the bars at the entrances of channels or at the mouths of streams, thus permitting large vessels to sail through. Tides have a value, also, in causing a back and forth flow of water in bays and inlets. These movements clean out any sewage and prevent unhealthy conditions. Progress also has been made in utilizing the difference in the level of the tides to store up water in inlets at high tide, and to develop power by letting it run out through the proper machinery at low tide. The height of tides varies somewhat with the shape of land formations. In the Bay of Fundy, tides of 60 feet have been recorded. Such tides increase the possibilities of tide water as a source of power.

Causes of the Seasons.—The change of seasons on the earth is due principally to the inclination of the earth's axis, the revolution of the earth around the sun, and the earth's distance from the sun. These cause variations in the intensity of the heat and light rays received from the sun.

Experiment to Show Causes of the Seasons.—To show that variations in the intensity of heat and light rays of the sun, resulting in the seasons, are due principally to the inclination of the earth's axis, the rotation and revolution of the earth, and its distance from the sun, use the same apparatus employed to illustrate the earth's motion around the sun.

Remembering that the axis of the earth inclines from the vertical 23½ degrees, place the globe at A with its axis pointing along the long axis of the ellipse, the top toward the center. Turn the globe on its own axis to represent the daily motion of the earth. Note that during a complete rotation on its axis its whole surface, at one time or another, receives rays from the sun with the exception of the south frigid zone. When the earth is at point A, the sun's rays fall vertically on the tropic of Cancer. The northern hemisphere as a whole has its warmest weather at this time. This is due to the sun's rays falling more directly on the northern hemisphere than on the southern hemisphere.

Move the globe to point B. Note that the sun's rays fall vertically on the equator and extend from the north to the south

pole. The relative temperatures in the northern and southern hemispheres are now about the same, while it is hottest at the equator because the sun's rays strike it vertically. When the earth is at the point represented by B, it is autumn in the northern hemisphere and spring in the southern.

Move the globe to point C, and then to D, and account for the variations in the intensity of heat and light on the different parts of the earth's surface.

Make a labeled drawing showing the path of the earth around the sun. Draw globes representing the earth at points C and D. Draw lines which show how the rays of the sun strike the earth on December 22 and March 21.

Solar Eclipse.—Whenever the moon comes between the earth and the sun a solar *eclipse* occurs; that is, the direct rays of the sun are prevented from reaching certain portions of the earth. The eclipse may be partial or total. It is partial when only a portion of the sun's disk is hidden, and total when the entire disk is obscured. Total eclipses are not common. One occurred on the 26th of January, 1925, that was visible in parts of this country.

Latitude and Longitude.—*Latitude* is distance in degrees north or south of the equator. *Longitude* is distance east or west of a certain pole-to-pole line, or *meridian,* known as the *prime meridian.* The prime meridian passes through Greenwich, near London, in England. Knowledge of the latitude and longitude of places is important in travel and in reckoning time.

A circle contains 360 parts, or degrees. The distance between the earth's equator and each pole, a quarter of a circle, is divided into 90 parts, each about 69 miles long, or 1/360 of 25,000 miles, the earth's circumference. Each part is called a degree and its sign is (°). The first east-west line, or parallel of latitude, north of the equator is 1°, or about 69 miles, from the equator. The parallel 2° north is twice that distance, and so on. All points on any one of these parallels are the same distance from the equator and from each of the other parallels. So if you know that a place you wish to locate is on the 9th, or the 43rd, or any other parallel of north latitude, you can easily estimate how many

miles it is north of the equator. The same method of measuring is used south of the equator.

F. E. Hewitt.

TOTAL ECLIPSE OF THE SUN, JANUARY, 1925

The large central figure shows the moon between sun and earth at the instant of total eclipse. All the other figures show views taken at different times as the moon passed in front of the sun. How long did it take the moon to pass completely across the sun?

In order, however, to get the exact location, you must also know the longitude of the place, that is, on what meridian it is located. Degrees are measured east and west from the meridian of Greenwich. There is a meridian 1° east, another 2°, and so on. To the west the meridians are numbered in the same way. In both directions they are numbered up to 180°. By knowing both the latitude and the longitude of a place one can readily establish its location.

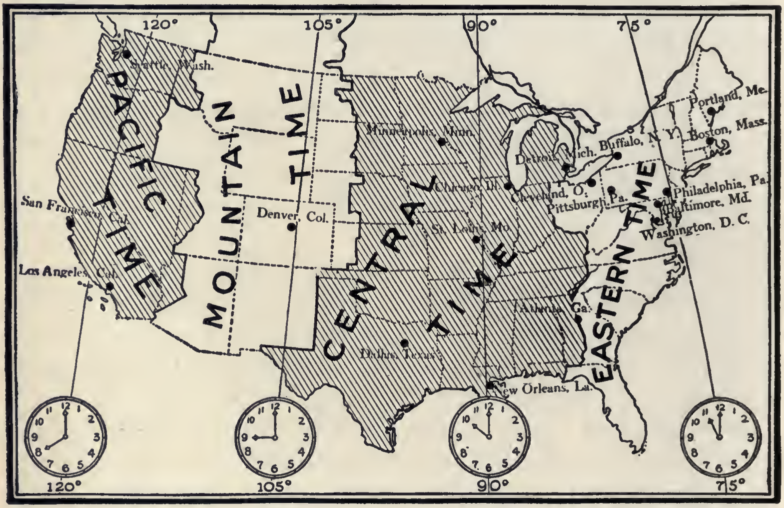
Solar Time.—The rotation of the earth on its axis gives us our day and night and our means of telling time. Before clocks were invented, people told time by means of a sun dial. This consisted of a horizontal plate on which was an upright pointer placed along a north and south line. When the sun caused the pointer to cast the least shadow, the time was called *noon.* From noon of one appearance of the sun until noon of its next appearance was called a *solar* day. This solar day was later divided into 24 periods or hours.

As the length of the solar day varies slightly with the seasons, an average uniform length of 24 hours was taken for it. To avoid starting a new day in the middle of the common working hours, this *civil* day was made to run from midnight to midnight.

All places on the same meridian have their solar noon at the same time. Places east of this meridian receive the sunlight earlier, and places west of it receive the sunlight later. For every 15 degrees of longitude east or west, there is a difference in time of one hour, because the earth rotates 360° in 24 hours, or 15° in one hour.

Standard Time.—Before the coming of railroads, each place used its own solar time without any inconvenience. But when people began to travel rapidly east or west, much confusion resulted as they found that their watches were always wrong, being too fast or too slow according to the direction they were traveling, since the solar time was different in almost every town. To avoid this confusion, and especially to aid the railroads in preparing their time tables, our government in 1883 adopted a system of *standard time.*

Under this system the area of the United States is divided into four time belts known as *Eastern, Central, Mountain* and *Pacific* belts. Throughout any one of these belts, standard time is the same, and each belt varies in time from a neighboring belt by one hour. Each belt uses the solar time of a specified meridian within its borders. These belt meridians are 15° apart. Only when a traveler passes from one time belt to the next, does he need to change the time of his watch. If he is going west, he



STANDARD TIME BELTS OF THE UNITED STATES

Why must we set our watches back as we travel westward across the country?

finds that his watch is one hour fast when compared with the time of the belt he has entered. If he is traveling east, he finds, as he passes from one belt to the next, that his watch is one hour slow. Accordingly, he must set his watch back one hour, or forward one hour, in order to conform to the standard time of the belt he has entered.

Each day at noon, eastern standard time, the exact time is telegraphed from Washington, D. C., to thousands of places in various parts of the country, for the regulation of clocks.

The Sidereal System.—The sidereal system consists of the stars—great blazing suns, all of which, except our own sun, are much farther away from the earth than any planet.

Stars and Constellations.—By means of the telescope, an instrument for seeing distant objects clearly, astronomers have discovered that there are in the heavens millions of bodies called stars. Without the aid of the telescope, the eye is able to see only about 7,000 of these, even under the most perfect conditions. But conditions seldom are perfect. Dust and vapor in the atmosphere, and the light of the moon, interfere so that usually only about one-third of these 7,000 stars are visible.

Yerkes Observatory.

THE SEVEN STARS OF THE BIG DIPPER
The two stars farthest from the handle point to the North Star.

In past ages, the Egyptians, Greeks and Romans observed the stars only with the naked eye. They thought they saw in groups of stars outlines of mythical heroes, animals, and other objects. Such groups of stars are known as *constellations.* There are nearly fifty of them, among which are the *Great Bear,* the *Little Bear, Lyra, Cassiopeia,* and the *Pleiades* or *Seven Sisters.*

The Great Bear.—One of the most interesting objects in the northern sky is the *Big Dipper.* It is always visible in our latitude when the sky is clear at night. It lies in the constellation of the Great Bear (Ursa Major). This constellation contains 133 stars that may be seen with the naked eye. The seven stars which

form the dipper are a part of it. It is quite easy to find the Big Dipper, but it requires the use of the imagination and considerable patience to trace the outline of the bear. The tail of the bear is formed by the handle of the dipper, and the two stars that outline the back part of the dipper are in the hind quarters of the bear. The two stars farthest from the handle, which outline the front part of the dipper, are known as the pointers, because they point to the North Star. The nose of the bear is supposed to be in front of the pointers. The bear's right forepaw and hindpaw are indicated by two small stars below. Two others, nearly in line with these, indicate the left hind paw.

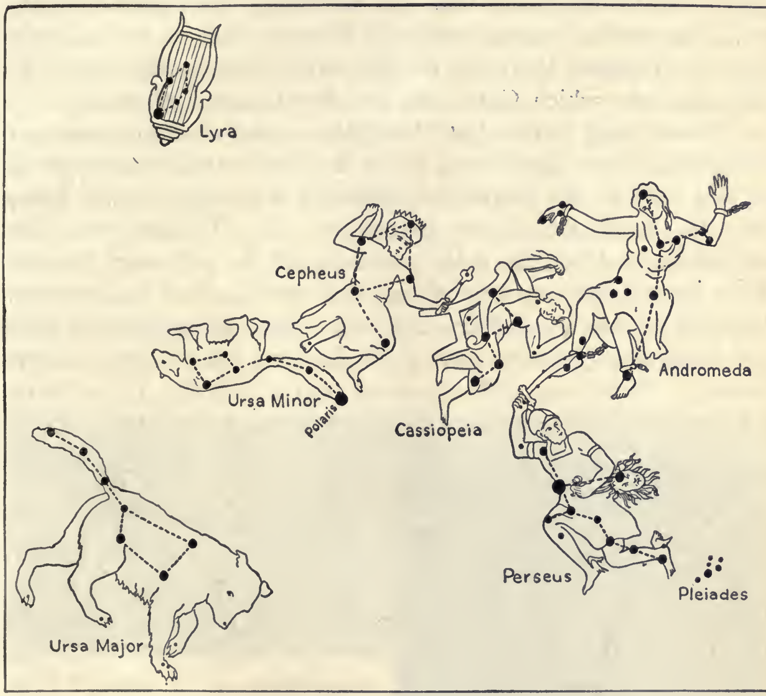
The Little Bear.—Another object of interest in the northern sky is the *Little Dipper,* also always visible in our latitude when the sky is clear at night. It consists of a cluster of seven stars and forms a part of the constellation of the Little Bear (Ursa Minor). The Little Bear is an interesting and important constellation, because the *North Star* forms a part of it. This star lies at the end of the tail of the bear and forms the end of the handle of the Little Dipper. Before the invention of the mariner's compass this was the star "whose faithful beams conducted the wandering ship through the wide desert of the pathless deep."

In former ages the North Star was the most talked of star in the heavens, because it was the guiding star not only of mariners but also of travelers on land. It is known as the pole star (Polaris) because the imaginary axis of the earth, if extended from the north pole, would reach the sky quite near it. It is also important because the other stars in the northern sky apparently revolve around it.

There is an interesting myth connected with the bear constellations. Juno, the Queen of Heaven, became jealous of Callisto, a beautiful woman, and changed her into a bear. Arcas, a great hunter, son of Callisto, did not recognize his mother in the form of a bear and determined to kill her. But Jupiter, King of Heaven, interfered and placed both of them in the heavens as the great and little bears. The handle of the Big Dipper, accord-

ing to the story, was formed by stretching the tail of the Great Bear when Jupiter lifted the creature up into the heavens.

Lyra, the Lyre.—This constellation is supposed to represent the celestial lyre upon which Orpheus, a famous mythical poet, produced such delightful music that wild beasts paused to listen, rivers ceased to flow, and rocks and trees stood entranced.



A Group of Familiar Constellations
Find them in the heavens.

It contains one brilliant star, Vega, located about 52 degrees from the North Star. This is one of the most attractive stars in the sky in the summer months. It is especially interesting to astronomers as the star which, 10,000 years hence, owing to the changing positions of the stars, will probably serve in place of the North Star for the people who will then inhabit the earth.

Cassiopeia.—Cassiopeia, containing 67 stars visible to the naked eye, lies about the same distance from the North Star as the Big

Dipper but on the opposite side. It is called the queen in her chair. Cassiopeia is represented as a queen seated on her throne. On her right is her husband, Cepheus, the king of Ethiopia; on her left Perseus, her son-in-law, and above her Andromeda, her daughter. There are constellations named after all these. The five brightest stars in Cassiopeia form an irregular W which opens towards the North Star. In mythology, Cassiopeia's daughter, Andromeda, was rescued by Perseus from a sea monster sent by Neptune, the ruler of the sea, to destroy the shores of Ethiopia over which Cassiopeia and her husband reigned.

Pleiades, the Seven Sisters.—This constellation lies south of the groups just described. It is the most conspicuous group in this part of the heavens. Although it contains many stars, only six are visible to the naked eye. The Pleiades were the daughters of Atlas, the deity who bore up the pillars of heaven. They were noted for their virtue and affection for one another. Pursued by the great hunter, Orion, they besought their gods for help, and Jupiter, pitying them, transferred them to the heavens. Mythology tells us there were formerly seven stars, but that one left her place in order not to behold the ruin of Troy of which her son was the founder.

Lick Observatory.

A Small Part of the Milky Way
Each point of light is a giant sun.

The Milky Way. — The luminous, cloud-like band which may be seen on any clear, moonless night across the heavens is called the *milky way,* or *galaxy.* It is composed of millions of stars, located much farther away than any of the bright stars. The North American Indians refer to it poetically as the "road of souls."

Why Stars Twinkle.— Each star sends toward the earth a tiny beam of light. The twinkling of the stars, which adds so much to the beauty of many a clear night, is caused by

the irregular passage of these beams through the air due to the unequal density, humidity and warmth of the different strata, or layers, of the atmosphere. As these layers of air pass between the observer and the star, the light may be alternately magnified and diminished.

Distance in the Heavens.—We have no conception of the great distances to many of the stars we see at night. Most of the stars are so far away that if these distances were measured in miles the figures would mean little to us. A new unit of measure has been devised to express these great spaces between the earth and the stars. This unit is the *light year.* The light year is the distance that light will travel in one year. Light travels 186,000 miles, about 7½ times the distance around the earth, in one second. Yet even at this terrific rate of speed it takes years for light to come to us from the nearest star. Some stars are so far away that light from them travels many thousand years before reaching the earth. No one can imagine these great distances. It is also probable that there are many more stars

Wide World Photo.

DISTANCE IN THE HEAVENS

Aldebaran is one of the nearest stars, yet the light we get from it today left it 44 years ago.

much farther away than those we have seen, for with each improvement of the telescope new and more distant ones come into view.

SUMMARY

The heavens include all the parts of the solar and the starry systems.

The sun is the center of the solar system, and is the largest body in it.

There are various theories in regard to the composition of the sun, of which Kirchoff's is the most generally accepted.

The sun provides radiant energy, that is, heat and light. It is the source of most of the energy in the solar system.

The earth is one of the planets. It revolves around the sun, making a complete revolution in 365¼ days.

The moon in her revolution around the earth presents different phases.

The principal causes of the change of seasons on the earth are the inclination of the earth's axis, its yearly revolution around the sun, and its distance from the sun.

A solar eclipse occurs when the moon passes between the earth and the sun.

Latitude is the distance north or south of the equator, and longitude is the distance east or west of a prime meridian.

Standard time refers to a system of time adopted by the United States government.

Stars are bodies in the heavens which form the starry system. Certain groups of stars make up constellations.

Among the principal constellations are the Great Bear, the Little Bear, Lyra, Cassiopeia, and the Pleiades.

The milky way is a luminous, cloud-like band in the heavens composed of a vast number of stars.

Twinkling of the stars is due to atmospheric conditions which magnify or diminish the light they send to the earth.

Fact and Thought Questions

1. What is included in the term "the heavens"?
2. Name several ways in which knowledge of the heavens is of value to man.
3. Describe Kirchoff's theory in regard to the composition of the sun.
4. What does the sun supply?
5. Mention the causes of the change of seasons on the earth.
6. What is the season in the Argentine republic during our mid-summer?
7. Give the cause of the phases of the moon.
8. What causes an eclipse of the sun?
9. Define: (a) latitude; (b) longitude.

10. Give, approximately, the latitude and longitude of your home.
11. What is meant by standard time? Name the time belts included in the United States.
12. An occurrence of news importance takes place in Europe in mid-afternoon. When would it naturally appear in New York papers?
13. What stars or constellations can you recognize?
14. Is it true or false that we have never seen part of the moon's surface? Why?
15. Mention and describe several constellations.
16. Why is the North Star, Polaris, considered important?
17. Why do not all planets have the same length of days and years as the earth?

Projects

1. Locate and chart the North Star and the Big Dipper.
2. Prepare reports on stories of constellations.
3. Chart the five constellations described in this chapter and outline the figures they are supposed to represent.

Outdoor Observation

1. Report on observations you have made on the effect of climate and the change of seasons on the life and habits of plants and animals. Also show how both plants and animals prepare themselves for these changes.
2. Observe the heavens on a clear night and try to locate four of the constellations named in this chapter.
3. Record observations of the brightness of the stars on successive nights, with notes as to general temperature and weather conditions.

References

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GENERAL THOUGHT QUESTIONS FOR DISCUSSION AND REVIEW

GROUP II

1. Did the pioneer have more, or less, control of his surroundings than the modern city dweller has?
2. Is the extent of the environment that affects one greater or less today than in the days before modern science?
3. Under what conditions does air become wind?
4. How would we be affected if matter could not change its form?
5. Is it true or false that water can be heated beyond the boiling point?
6. Why does a cement sidewalk or a pavement sometimes "buckle" in hot weather?
7. Explain:
   (a) A saw becomes hotter in sawing hard wood than in sawing soft wood.
   (b) Birds "fluff" their feathers to keep warm.
   (c) There is always a little space left between the successive steel rails of a track.
8. Why do we have some cool days during a hot summer?
9. Why does a sharp thunderstorm cool the air?
10. Is it true that a stove is superior to a fireplace for heating? Why?
11. Why is water used in automobile radiators?
12. Is it true or false that a seashore often has rain when it is snowing inland?
13. What causes water to percolate in a coffee percolator?
14. How may a room be aired most quickly?
15. Why is it that a steam heating system warms a room more rapidly than a hot water system?
16. Is there more, or less, air in boiled water than in water as drawn from a faucet? Why?
17. Why does a water pipe burst if water freezes in it, but a pail containing water is not affected under the same circumstances?
18. Why is it that one may fan a spark to a flame by blowing on it and yet put a candle out by the same means?
19. State several differences between the sun and the moon.
20. Why can't we see the stars during the daytime?
21. William discovered a fire in a closet. He left the door open and ran for water. What mistake did he make? Why?
22. Why do you blister your hands if you slide down a rope rapidly?

23. Is a hot air, a steam, or a hot water system better for ventilating a building?
24. Why are furnaces and pipes often covered with asbestos or similar materials?
25. Why does a hot forest fire start a wind even on a windless day?
26. What would be likely to happen if a cold tumbler were placed inside one just heated in hot water?
27. Why do we oil machinery?
28. Why is it possible to tell the direction of a light wind by holding up a moistened finger?
29. Why does loosely woven clothing often keep us warmer than clothing of close texture?
30. Explain the lessening of a wind at sunset.
31. Name several changes that would be brought about if the earth stopped rotating on its axis.
32. Why does water whirl when draining out of a sink?
33. Explain why flatirons often have handles of wood or coiled wire.
34. How may you reduce the smoke caused by adding fuel to a fire?
35. Why are telescope rooms in astronomical laboratories not heated?
36. Why are fires especially troublesome when they start in partitions?
37. How does the moon affect the earth?
38. Why do steam pipes seem to snap and pound when heat is turned on?
39. Why do water pipes pound when water is turned off sharply at the faucet?
40. Why do greenhouses have glass tops?
41. Why does water kept in a porous jar stay cool in hot weather?
42. Why do houses damaged by a tornado often appear to have been blown apart from the inside?
43. Could we use any other star than the North Star as a guide if lost in the wilderness without a compass?
44. Is it true or false that a barometer reads the same at a given hour in all localities?
45. Suppose there were placed before you a cup of mercury, a glass tube 34 inches long and a shallow dish, in order that you may use these materials to perform a certain experiment.
    a. What experiment could you perform by using these materials?
    b. Describe just what you would do in the experiment.
    c. Show by a labeled drawing what would happen in this experiment.
    d. What conclusion would you draw?

CHAPTER XII

SOUND

Sound is one of our greatest blessings. By means of sounds we talk with one another when together and even when hundreds or thousands of miles apart. Sounds warn us of dangers. Sound-signals control many of our acts. Sound in the form of music brings real enjoyment to most of us.

We all know that sound travels. We see a distant wood chopper swing his axe against a log, but the blade often is high in air again before the sound of the blow comes to us. How sound is produced, how the air and other substances aid in carrying the sound message, and how the wonderful mechanism of the ear receives the message and transmits it to the brain, should all be part of our scientific knowledge.

We are all familiar with the fact that if we toss a stone into still water, or stir it with a stick, tiny waves, or ripples, are caused. This disturbance of the water spreads out in all directions for a considerable distance. In the same way, the motion of any object in the air about us causes air waves which spread out in all directions. If the object causing the air motion is vibrating, or quivering, that is, moving very rapidly back and forth, the air waves it sets in motion cause the sensation of sound when striking our ears.

Sound is always the result of motion. Energy is necessary to produce motion. So we may say that sound is the result of a transformation of energy.

Experiments to Show How Sound Is Carried.—That sound is usually transmitted to our ears through the air from a vibrating body may be shown by a simple experiment. Place a metronome, an instrument used to keep time in music, on a piece of felt on the receiver of an air pump. Set the metronome in motion and cover it with a bell jar, being careful that the metronome does not touch the glass. Notice the sound. Pump the air from the

jar and notice that the sound gradually dies away. Let the air into the jar again and notice that the sound is again heard and continues to grow louder.

A similar experiment may be performed by using an alarm clock set to ring while under the bell jar.

These experiments show that sound is transmitted by the air. Air, however, is not the only substance that will transmit sound. Have someone stand at the farther end of a long table and scratch it lightly with a pin. You cannot hear it. But if you place your ear against the table you can hear it readily because the wood carries the sound to you. This is an example of sound being carried by another substance than the air. Sound may be transmitted by any gas, liquid, or solid. Remember that both matter and energy are needed to produce sound and to carry it to us.

Speed of Sound.—We all know that sound requires time to travel to our ears. Perhaps you have watched a distant engine when its whistle was blown. If so, you noticed that the steam rushed from the whistle an instant before you heard the sound, and you continued to hear the sound for an instant after the steam stopped rising from the whistle. Perhaps, also, you have watched a carpenter in the distance driving a nail, and have noticed that his hammer was raised for another blow before you heard the sound of the preceding one.

Experiments to Show the Speed of Sound.—To show the speed of sound, have one person pound something uniformly. As you watch him, move away as rapidly as possible. Notice that the interval that elapses between the time when you see the hammer strike and the time when you hear the sound of the stroke increases with the distance. If you continue moving away, you will finally reach a point where the hammer will appear to strike at exactly the same time you hear a report. This is because time enough elapses between the blow and the report for the hammer to be raised and brought down a second time. If the person stops pounding, notice that you receive one report after the pounding has ceased. If you time the blows struck by the hammer, and then measure your distance from this point to the hammerer, you have the time needed for the sound to

travel to you. In this way you may calculate the speed of sound in air.

Sound does not travel at the same rate in different substances. To prove this, stand on a railroad and watch someone in the distance strike a blow on a rail. If the ear is placed against the rail you will hear the sound through the rail and then hear it a second time through the air. It must have traveled faster in the rail than in the air. Air is very light and will not carry sound as fast as iron, which is very heavy. Any heavy substance, such as iron, is said to have a *high density,* while anything that is light is said to have a *low density.* The speed of sound is affected by the density of the substance through which it passes. The higher the density, the faster sound travels.

Intensity of Sound.—Intensity of sound, or loudness, depends upon the force with which the body producing the sound is vibrating, and also upon the substance through which the sound is carried. The experiment with the metronome under the glass receiver showed that the intensity of the sound became less as the air under the receiver became less dense. It is said that at high elevations, as the air becomes rarer, explorers find that the distance at which the voice can be heard becomes less. At sea level, the firing of a gun produces a sound much louder than on a mountain top.

Sounds are always louder when the air surrounding the sound-making body is dense than when it is rare. You have perhaps noticed that the sound of a bell seems louder in cold than in hot weather. Cold air is denser than warm air.

Experiments to Show Production of Sound by Vibrations.—Ring a bell, blow a whistle, strike a drum, and snap a taut wire. Do each of these things gently, and then forcibly, and observe in each case what occurs. Listen to the sound each makes. Stop the vibration of the wire. Does the sound continue? Was it the vibration that caused the sound?

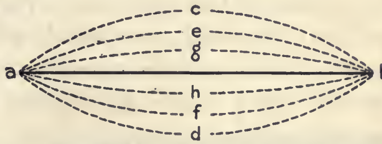
When a bell is struck, the sound travels equally well in all directions if the density of the medium through which it passes is uniform and there are no objects to divert the waves. You have noticed how waves form in the water when a stone is

thrown into it. They start at the point where the stone strikes the water and radiate outward in ever-widening circles. Sound waves travel in the same way, except that the waves are spherical, or ball-shaped. Just as the circles enlarge in the water, so the spheres enlarge in the air as the waves move outward from the sound-making body.

In a whistle, the air is set in motion by blowing a current from the lips across a thin metal edge, causing it to vibrate. The sound is transmitted through the air in the form of waves.

When the drum is struck the diaphragm vibrates, starting sound waves in the air.

When a wire is snapped, its vibrations set the air in motion. The sound produced by a string of a musical instrument is the result of this motion. Let a line *a—b* represent such a string. If the string be drawn up to *c* and released, its elasticity will not only carry it back but will give it force enough to carry it to *d*. From thence it will successively return to *e, f, g, h,* and so on, until the resistance of the air stops its motion.



VIBRATION OF A TAUT WIRE

The action of the bell illustrates how music is produced by a carillon, a chime of bells upon which tunes may be played. The action of the whistle illustrates the principle involved in the production of music by the flute, the organ and other wind instruments. The action of the wire or the string illustrates how this principle is involved in the production of music on the harp, the violin, and other stringed instruments.

The Tuning Fork.—A device called a tuning fork is used in tuning musical instruments. It consists of a forked piece of steel, which vibrates at a given rate when struck, and so produces a certain fixed tone or note. When the pitch of the corresponding note on the instrument being tuned is the same as that of the tuning fork. this note is used as the basis for tuning the instrument.

The Piano Player.—A piano player is an instrument which operates by air pressure, to reproduce music. There is a

chamber in the instrument from which the air is removed by means of a pump which is operated by the feet or by electricity. Connected with this chamber is a metal tube, known as a tracker bar, in which are a number of holes. Air entering one of these holes causes a hammer to strike a certain string in the instrument, thus producing a certain note. When the piano player is in use, a partial vacuum is maintained in the chamber, and so the pressure of the atmosphere tends to force air into each of the holes and to operate its hammer. A perforated strip of paper, the record of the music to be played, is passed across the holes, and only the holes over which the perforations pass are exposed to the pressure of the air. By this means any note, or combinations of notes, can be played, and thus music is produced.

Syracuse Symphony Orchestra.

A Symphony Orchestra

Locate several types of musical instruments and tell how each produces sound.

The Voice.—The human voice is produced in a box-like structure, called the *larynx,* located at the top of the windpipe. The lump on the front of the neck, popularly spoken of as Adam's apple, is part of this larynx or voice-box.

In the larynx are the *vocal cords,* consisting of two thin projecting membranes of elastic tissue, between which there is a narrow opening called the *glottis.* In breathing, these membranes are very loose and air passes between them without causing sound. In producing sounds these membranes, or vocal cords, are brought close together by muscular action and made more or less

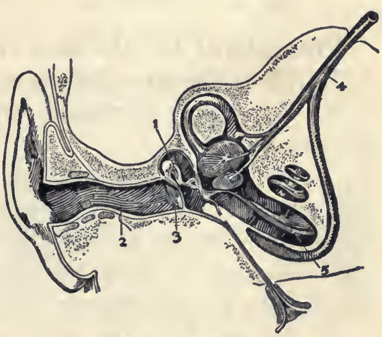
tense, and currents of air coming through the glottis from the lungs cause them to vibrate. The pitch of the voice depends upon the greater or less tension of the vocal cords. Its volume depends largely upon the force with which the air is expelled from the lungs.

The Phonograph.—A phonograph is a machine for reproducing sounds. These sounds must first be recorded. In doing this, the sound waves are allowed to strike against a thin disc which they cause to vibrate. This vibration is transmitted to a needle attached to the disc. The point of the needle rests upon a flat, circular wax plate which revolves at a regular rate. As the needle vibrates it cuts a groove of irregular depth in the wax. Later this wax record is copper plated, and from it duplicates are made on a rubber-like substance which becomes very hard when it cools.

These records are played on a machine much like that used to make them. As the record revolves, a needle which rests in the groove is caused to vibrate in just the same manner as the needle which cut the groove. This vibration is transmitted to a thin disc, which sends it forth as sound waves in the air. Thus, sound waves which are recorded on the record are reproduced when the record is played.

The phonograph principle is applied to dictating machines. The person dictating speaks into a receiver and his message is recorded on a cylindrical wax record. It can then be reproduced from the same record.

The Ear.—The ear is the organ of hearing. It is wonderfully adapted for receiving sounds. The ear has three main divisions, the *outer* ear, the *middle* ear and the *inner* ear. The outer ear is oval and somewhat funnel shaped, and therefore



THE EAR

1. Hammer, Anvil and Stirrup.
2. Auditory Canal.
3. Ear Drum.
4. Auditory Nerve.
5. Cochlea.

Locate the outer, middle, and inner ear.

well adapted to catch and converge sound waves. It encloses the *auditory canal,* or passage, which at its inner end is covered with a membrane called the *ear drum,* or *tympanic membrane.* This membrane receives the sound waves and transmits them through the middle ear to the *cochlea,* the real organ of hearing.

The middle ear is a small chamber in the bones of the head, located at the inner end of the auditory canal and separated from it by the ear drum. Immediately in contact with the ear drum and connecting it with the inner ear is a chain of three small bones which, because they resemble a *hammer,* an *anvil,* and a *stirrup,* have been given these names. A passage, called the *Eustachian tube,* connects the middle ear with the mouth and thus protects the ear drum by equalizing the air pressures on its two sides. For this reason, it is well to have the mouth open during loud, sudden noises, such as explosions.

In a bony cavity immediately beyond the middle ear lies the inner ear, consisting of two parts, the *semi-circular canal,* and the *cochlea,* a spiral tube full of liquid which transmits sound. Sound waves set the ear drum vibrating and this movement is carried through the three bones of the middle ear to the cochlea, through the liquid in the cochlea to delicate nerve cells on its inner surface, and from them through the auditory nerve to the brain.

Precautions for the care of the ears.—

1. Keep the ear openings clean and dry.

2. Do not try to remove ear wax with a pin or other hard instrument.

3. In case a seed or other foreign body gets into the ear, have a doctor remove it. An insect can usually be removed without difficulty by the use of water or sweet oil.

4. In case of very loud noises, open the mouth so as to equalize the air pressure on the ear drums.

5. Do not blow the nose too violently, since disease germs may be driven through the Eustachian tube into the middle ear and cause serious infection.

6. In case of earache make outside heat applications—hot water bags or heated flannel.

7. Do not neglect a gathering in the ear. The germs from it may cause a dangerous disease requiring a surgical operation.

To Test the Hearing.—In a quiet room, a person with perfect hearing can hear a loud-ticking watch at a distance of several feet. To determine whether a person has approximately normal hearing, hold such a watch five feet from each ear in turn, while covering the other ear. If the watch has to be brought within three feet of the ear before the sound of the ticking is heard, the hearing of that ear is about three-fifths normal; if within two feet, two-fifths normal, and so forth.

Reflection of Sound.—Sound waves in the air are reflected when they come against walls and other barriers. Since sound sends out waves in all directions, a listener in a room hears both the original sound and its reflections. The reflections, if immediate, may intensify the sound. Otherwise they may interfere with its sharpness. Frequently the voice of a speaker is more distinct in a crowded hall than in an empty hall, as the presence of people helps to break up troublesome reflections of the speaker's voice. Sound, like light, after it has been reflected from several surfaces, may be focused, or collected into a single point, where it will be heard better than at any other point. The famous whispering gallery of St. Paul's church in London is constructed on this principle. Persons at opposite sides of the huge gallery are able to hear each other when they merely whisper. The sound is carried from one person to another by the reflections along the curve of the dome. Similar odd effects occur in Statuary Hall of the Capitol at Washington, D. C.

Ernest F. Conway.

A Place Where Echoes May Be Heard

Echoes.—An echo is caused by sound vibrations coming against a large surface, such as a massive rock, the side of a large building, a hill, or woods, at some distance from the source of the

sound and being reflected back to the ear. Megaphones and hearing trumpets are so constructed that they use the reflection of sound to intensify it.

SUMMARY

Sound is caused by the striking on the ear of air waves from a vibrating body.

Sound may be transmitted through all solids and liquids as well as through air and other gases.

The intensity of sound depends upon the density of the medium through which it travels.

Sound travels equally well in all directions in the same substance, provided there are no objects that divert the sound waves.

Sound waves may be started in such ways as by blowing a whistle, snapping a taut wire, or ringing a bell.

Voice is produced by the vibration of the vocal cords in the larynx.

The phonograph is an instrument capable of reproducing the human voice or other sounds.

The ear is the organ of hearing. It has three main divisions.

Sound waves in the air are reflected when they strike against walls or other barriers.

An echo is a reproduction of a sound caused by the reflection of sound waves back to the ear.

Fact and Thought Questions

1. What is sound?
2. If plaster fell from a ceiling in a vacant room and there were no ears there to hear it, would there be any sound?
3. Suggest several ways in which sounds are used as warnings.
4. Name sounds about the home and neighborhood, other than the speaking voice, that convey information to you.
5. What use do automobile repair men make of sound?
6. Through what substances will sound pass?
7. How does the density of a medium affect sound? Illustrate.
8. Describe an experiment to show the production of sound.
9. Describe the action of a piano player.
10. Explain the production of the human voice.
11. Describe the ear.

12. Why will "an ear to the ground" bring us many sounds before we can hear them by standing erect?
13. What is meant by the reflection of sound?
14. Is the distance sound "carries" affected by the wind? Why?
15. Does the direction from which sound comes to us affect our hearing of it?
16. Is it true or false that sound travels faster than light? Give one reason for your answer.

Projects

1. Demonstrate the transmission of sound through liquids.
2. Demonstrate the structure and function of the ear by the use of a model.

Outdoor Observation

Observe how familiar outdoor sounds in your general neighborhood are affected in intensity and clearness by wind, fog, and other weather conditions. Observe if they are different by day than by night. Record your observations.

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CHAPTER XIII

LIGHT

All day long light waves from the sun arrive in countless trillions. They make it possible for us to see our way about, to avoid dangers and to do our work. They bring color and beauty everywhere to delight our eyes. Flashing through camera lenses, they even paint pictures for us. They bathe and penetrate our bodies in health-giving streams. They destroy disease germs. They purify water. Beating on the countless green leaves of growing plants, they do necessary work in making food for us to eat.

So many, indeed, are the benefits of light that for ages man has sought to drive away the darkness of night by artificial light. Even this light, however, is due to the sun, for it is the sun that has stored in the materials man uses the energy that is turned into light.

To understand the way light acts is to understand many of our daily experiences and how the wonderful mechanism of our eyes enables us to use and to enjoy light.

We know that light is a form of energy. It may be produced from other kinds of energy, such as electricity or intense heat, although the source of both light and heat is the sun.

How Light Travels.—There have been several theories advanced to explain how light comes to us, either from the sun or reflected from some other object. The theory that has been most widely accepted is that it travels as a wave motion in *ether,* a medium which is supposed to fill all space, even between the molecules of the densest material. Ether is very elastic, and so allows waves to pass through it with very little loss of energy. Heat and light waves pass through ether in straight lines in all directions from the source. Taken together they are called radiant energy. This theory was first proposed by Christian Huygens in 1678, but was not generally accepted until within the last century. Some scientists now question this theory.

Light waves are very short. Even the longest are only about 0.000027 of an inch in length. The most careful measurements show that they travel at the rate of about 186,000 miles, or seven and one-half times around the earth, in one second.

As we watch the ocean waves come up to the shore, we notice that they travel one behind the other at regular intervals. If we were to count the number which come up per minute we would have a means of measuring the rate at which they are formed. This is sometimes called the *frequency* of the wave motion. The frequency of the longest wave motion which we can recognize as light is about 400 trillions per second, while the shortest wave motion which results in light is about 700 trillions per second.

There are many waves in ether which are longer than the light waves. Those which are only slightly longer are known as heat waves. These heat waves explain how the heat comes to us from the sun. They travel at about the same rate as light. *Radio* waves are of a similar nature, only much longer, some being miles in length.

A light *ray* is a single line of light, too small to be visible. A group of parallel rays is called a *beam* of light. If the rays are not parallel, but come to a point, they form a *pencil* of light.

Some materials stop light rays and others permit them to pass through. A material through which light passes so perfectly that we can see objects on the far side of it is called *transparent.* Window glass is an example of transparent material. A material through which light passes, but not perfectly enough so that objects can be seen on the other side of it, is called *translucent.* A piece of thin paper and a pane of frosted glass are translucent. If no light passes through a material it is said to be *opaque.*

Color.—The different colors which we see are due to the variations in frequency of the light waves. The longest waves, which have a frequency of about 400 trillions per second, appear to us as red, while the shortest, which have a frequency of about 700 trillions, appear as violet. Other waves which range between

these limits of frequency give the colors that appear in the rainbow between red and violet. The colors which are found in sunlight are the rainbow colors, red, orange, yellow, green, blue, indigo, and violet. All other colors are merely two or more of these colors combined.

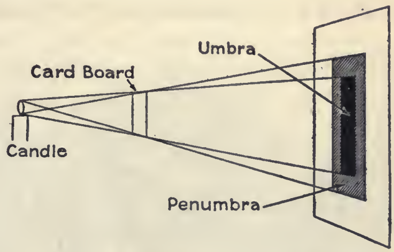
The color of an object, then, is determined by the length of the light waves which it sends to our eyes. Sometimes the color of an object seems to change. This may depend on whether the light waves come to us through the object or are reflected back to us from its surface. A thin piece of gold leaf gives a very good example of this change of color. If we place the gold leaf between two pieces of glass to hold it in position, and then lay it flat on the table, it will send back to us the yellow color of gold; but if we hold it up between some source of light and our eyes the color that comes to us is green.

Experiment to Show that Light Rays Travel in Straight Lines.—Punch small holes in the centers of two pieces of cardboard, and set the pieces upright on separate supports, a few inches apart. Light a candle and adjust the pieces of cardboard so that you can look through both holes and see the flame beyond. Is the line from the flame to your eye a straight line? From this do you conclude that light rays travel in straight lines?

Shadows.—Any object that will not transmit light will cut off or deflect it. Then a dark space, known as a *shadow,* will be cast on the side away from the light. This shadow changes with any change in the position of the light. For example, the shadow of a tree cast by the sun at noon is far different from its shadow in late afternoon when the sun is low in the west.

Experiment to Show the Nature and Cause of Shadows.—Place a piece of white cardboard on a support between a lighted candle and the wall in a darkened room. First, place the cardboard near the wall and note the type of shadow that is produced. Then place the cardboard some distance from the wall and note the shadow formed. The first observation will reveal a clear-cut dark shadow. The second will give a rather indistinct shadow, dark in the center and somewhat lighter at the edges.

Each point of light in the candle flame casts a shadow. The light from the top of the flame casts one shadow, the light from the bottom another, and so on. These different shadows overlap and form a dark space near the center of the shadow, known as the *umbra*. Around the umbra is a somewhat lighter space, the *penumbra*, formed by light from one part of the flame falling on the shadow cast by another part.



How a Shadow is Formed

Reflected Light.—Whenever light strikes an object, some of the light is absorbed and some is turned back to us, unless the object is black. A black object will absorb all of the light and none will be turned back. When light is turned back it is said to be reflected. The path over which the light is reflected is fixed. This path is determined by the angle at which the light strikes the reflecting surface. The angle at which the light strikes a plane surface is equal to the angle at which it leaves it.

Reflection of Light Rays

Notice the difference in the manner of reflection from smooth and from rough surfaces.

Mirrors.—A mirror is a very smooth surface which reflects light. Mirrors are usually made either by polishing a piece of metal, as those often seen in camping outfits, or by covering one side of a piece of glass with silver or a mixture of mercury and

tin. In making mirrors, the thickness of the glass must be uniform or the image will be distorted.

When one looks into a mirror his image seems to be just as far behind the mirror as he is in front of it. The image is also reversed. This is shown by standing in front of a mirror and

Great Northern Railway.

REFLECTIONS IN NATURE'S MIRROR

raising the right hand. Notice which hand the image raises. The same change of image may be shown by trying to read a book by observing its image in a mirror.

When several rays of light are reflected from a mirror, they leave it bearing the same relation to one another that they had before coming in contact with it. If they were moving parallel to one another before striking the reflecting surface, they remain parallel to one another after leaving it. If they were coming together as they approached the mirror they continue approaching one another after they leave it. If they were drawing farther apart when they struck the mirror, they continue to separate.

Curved Mirrors.—All mirrors do not have plane, or flat, surfaces. Mirrors for special uses are made with their surfaces curved in many different ways. Those in most common use are

the *concave* mirror of which the front surface is hollowed out like a portion of the inside surface of a hollow sphere, and the *convex* mirror, where the front surface is curved out like a portion of the outer surface of a sphere.

The concave mirror magnifies, producing an image larger than the object reflected. This type of mirror is used in telescopes, in shaving glasses, and wherever a large, clear image is necessary. Concave mirrors are used also as reflectors in automobile headlights. The area of the lighted portion in the road ahead can be varied by adjusting the distance of the light in front of the mirror.

The convex mirror makes a small image of a rather large field in front of it. This type of mirror is often placed on automobiles so that the driver may get a view of the road back of him without turning to look to the rear. The image in such a mirror is small, but it shows the entire width of the road for some distance back.

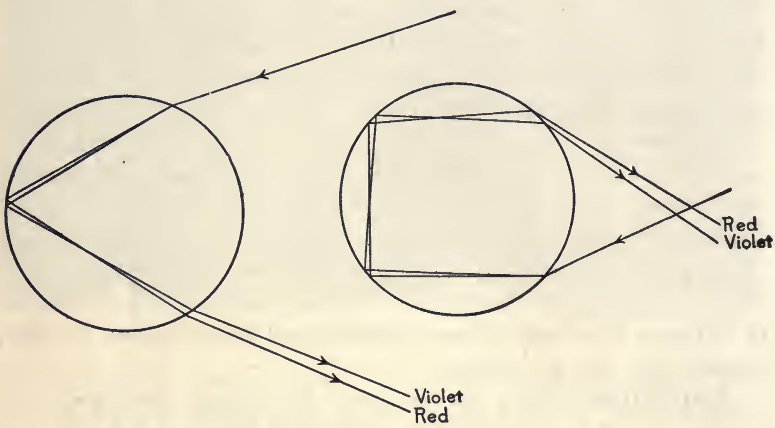
Diffusion.—Parallel rays of light are also reflected from surfaces that are not smooth, such as a piece of paper. A reading glass shows that even the best glazed paper is rough. In such cases the rays do not bear the same relation to each other after striking the paper that they did before. The different rays strike the uneven places in the paper at different angles and are reflected in different directions. Such reflection we call *diffusion* of light, because the rays are mixed.

Refraction.—Light waves travel in straight lines and at a uniform speed as long as they continue in the same substance or medium, but when they pass into some other medium the speed is changed according to the density of that medium. The denser the medium the more difficulty the light experiences in passing through it. Light travels at the rate of 186,000 miles per second in air. It travels only about three-fourths as fast in water, and about two-thirds as fast in glass. On the other hand, it has been discovered that light travels at a faster rate in gases that are lighter than air, and still faster in a vacuum.

When a beam of light passes at an angle from air into water, it is bent downward into the liquid. This accounts for the apparent bending of a stick thrust into water. Any beam of

light when passing at an angle from one medium into another of different density is bent, or *refracted.*

The Spectrum.—White light is not a simple color, but is made up of the seven primary colors, all of which have waves of different lengths. Thus when sunlight is passed through a triangular glass prism, the primary colors separate, each being bent a different amount, according to its wave length. The red rays are bent the least, and the violet the most. As a result, the white light is broken up, and in its place we have a band of seven colors—red, orange, yellow, green, blue, indigo, and violet—which we call the *spectrum.*



HOW RAINBOWS ARE FORMED

Raindrops break white light into the spectrum colors. If there is single refraction, as at the left, the seven colors appear in the order commonly seen in the rainbow. If there is double refraction, as at the right, there is a second rainbow whose colors are reversed.

The Rainbow.—Everyone is familiar with the rainbow, so often seen in the early forenoon or late afternoon on showery days. It appears when the sun begins to shine through the clouds while the rain is still falling. In order to see the rainbow the observer must stand with his back to the sun, as the rainbow always appears in the opposite side of the heavens from it. Why?

As the sun shines through a raindrop, the light is broken up into its colors, as in a triangular prism. Each drop shows all of the colors, but at different angles. A drop high in the air may send red waves directly to your eyes, the other colors passing overhead. A lower drop is meanwhile sending you violet, and other drops, between the two, supply the remaining colors of the spectrum. The thousands of falling raindrops thus give a continuous spectrum across the sky. Sometimes the light strikes a higher set of raindrops, and by double refraction in these drops causes a second rainbow, above the first, and with the colors reversed.

Lenses.—A lens is a piece of transparent glass so made that its surfaces are not parallel, and at least one is curved. It is used for bending light rays. One lens may be of such shape that it will spread the rays from a beam. Another lens may bring the rays closer together, in which case it is said to focus them. This means that if they are allowed to continue without interruption the light rays will come together at some point known as a *focus*. Lenses are made in many different shapes.

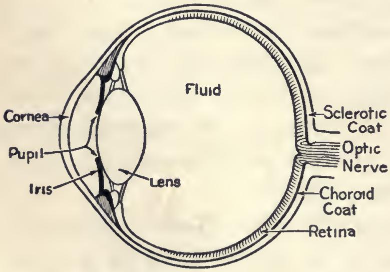
Lenses may be divided into two classes. *Convex* lenses are thicker in the center, and tend to bring the light to a point. *Concave* lenses are thinner in the center and tend to spread the light. The most common use we have for these two forms of lenses is in making eyeglasses. The convex lens is also used in the camera and in the projection lantern.

If a beam of light is allowed to pass through a darkened room, from a hole in the window shade or from a projection lantern, it may be seen as dust particles in its path become illuminated. This effect can be increased by tapping a blackboard eraser in the light streak to add dust particles. If lenses of different shapes are held in this beam of light their effects may be noticed, either by observing the changes in the beam, or in the light spot on a cardboard held in position back of the lens.

Sight.—The eye is the organ of sight. Its parts are the *cornea,* the *sclerotic coat,* the *iris,* the *pupil,* the *lens,* the *retina* and the *choroid coat.* The three most essential parts are the iris,

the lens, and the retina. The iris regulates the amount of light striking the lens. The lens focuses the rays of light on the retina. The retina receives impressions of objects, called images, and transmits them to the brain through the *optic nerve.*

Comparison of the Eye with a Camera.—There is a resemblance and a difference between the eye and the photographic camera. Both are lightproof except where the light coming from the object enters through the lens. The pupil of the eye corresponds to the diaphragm, or adjustable opening, of the camera; the lens and cornea to the lens of the camera; and the retina to the sensitive film, or plate. The differences are in the methods of focusing and in the nature of the sensitive plate and retina.



A Cross Section of the Eye

In the eye, adjustment for distances from the object is by means of a change in the curvature of the surfaces of the lens, but in the camera this is done by changing the distance between the lens and the plate. In the camera the sensitive plate should receive but one impression, and then the picture must be developed. In the eye, the picture on the retina passes quickly and the retina is always ready for a new impression, though each impression received may be stored away in the brain.

To show that images are inverted in the camera, point a camera at a lighted object, look on the ground glass finder and notice how the object appears. Using a model or chart of the eye, explain its structure and how it acts like a camera.

Accommodation.—The adjustment of the lens of the eye to suit different distances from objects is called *accommodation.* Eyes unable to see distant objects clearly are called *nearsighted.* Eyes that perceive objects at a distance more clearly than objects near-by are called *farsighted.* Convex glasses correct farsightedness, and concave glasses correct nearsightedness.

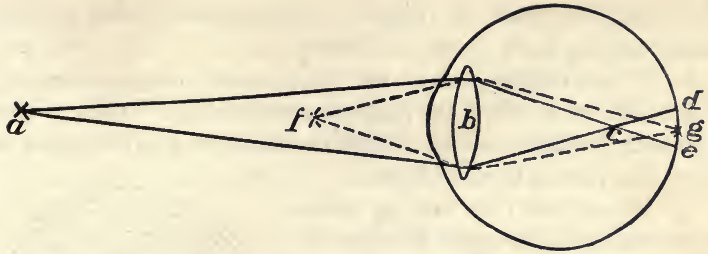


DIAGRAM OF THE EYE IN NEAR SIGHT. THE DEFECT IS REMEDIED BY CONCAVE GLASSES

The lens *b* brings the rays from a point of light *a* together at *c* too soon. So the rays cross and fall over the whole surface of the retina from *d* to *e* making a confused image instead of a clear point. When the rays are spread apart by bringing the light near the eye, as at *f*, they come together farther away upon the other side of the lens, as at *g*. Thus they fall upon a single point of the retina and produce a clear image.

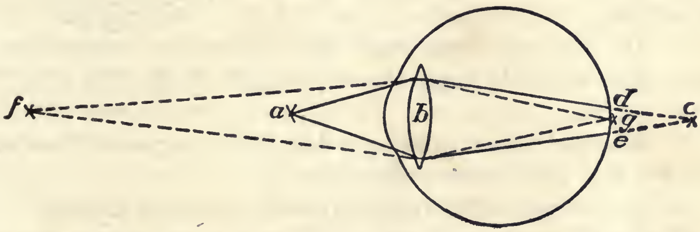


DIAGRAM OF THE EYE IN FAR SIGHT. THE DEFECT IS REMEDIED BY CONVEX GLASSES

The lens *b* does not bring the rays from a point of light *a* together soon enough. So the rays fall over the whole surface of the retina from *d* to *e*, making a confused image instead of a clear point. When the rays spread less apart, as when the light is moved farther away, to *f*, the lens brings them together sooner. Then the rays fall upon a single point of the retina at *g*, and thus form a clear image.

Astigmatism.—Astigmatism is a defect in the eye due to irregular curvature of the cornea or of the lens, making it difficult to see equally well lines running in different directions. Such a defect causes strain of the eye muscles in changing the focus so as to try to get a clear, distinct image. The effort often causes headache and nervousness. Glasses are required to remedy this defect.

Precautions for the care of the eyes.

1. Avoid using the eyes where there is insufficient or unsteady light.

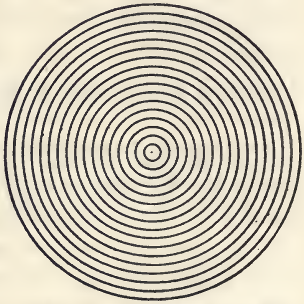
2. Do not read in twilight. Unconsciously the eyes are strained as the light becomes dimmer.

3. When reading, sit so that light comes from behind over the shoulder and strikes the page perpendicularly. When writing, sit so that the light over the shoulder causes no shadow to be cast on the line that is being written.

4. Do not read on moving trains or automobiles as it is difficult for the eyes to adjust themselves to the constant changes of position, and eyestrain results.

5. Do not read while lying down, for too much light enters directly into the eyes and not enough falls on the printed page.

6. Do not read books with very small type or with pages having a glossy surface.



HAVE YOU ASTIGMATISM?
With one eye closed look at this figure. If the lines seem blurred, there is astigmatism.

7. Rest the eyes frequently. Like other organs of the body, the eyes tire and require relaxation.

8. If the eyes are defective, consult an oculist at once.

Motion Pictures.—A motion picture camera takes a series of small photographs on long strips of film, each picture including slightly different successive positions of all moving objects. When these films are run through a motion picture projector, the pictures are thrown in rapid succession on a screen. As the retina of the eye retains each picture until the next has taken its place, the slight changes of position blend, and an impression of continuous motion is produced.

Artificial Lights.—We have already discussed the fact that heat waves seem to differ from light waves only in that they are a little longer. The higher the temperature, the shorter the heat waves. If the temperature becomes high enough, light will result.

Man has searched for a long time to find a source of light without heat, but up to the present he has not been able to produce such a light. Back in the distant past man had no artificial light. He first learned to kindle a fire. Then he gathered

with his friends around this fire where he could make use of the light given off. He soon learned to carry blazing sticks a short distance from this fire to help him in finding his way. Later he came to use wood soaked in pitch, or in oil from the animals he killed. Later still he learned to make candles from tallow with strings through them for wicks, similar to the paraffin candles of today.

The candle was the principal source of artificial lighting until long after the Revolutionary war. With the discovery of petroleum, came the oil lamp. Then came natural gas, which is found in many parts of the earth, usually in regions where petroleum is procured. Man then learned to make gas from coal. Later he learned to make acetylene, a gas which is formed by the action of water on calcium carbide. Today we have electric light. Houses, stores, and streets are ablaze with it. With its use factories may operate all night when necessary.

If a cold piece of glass is held over a candle flame, it will soon be covered with black soot. Soot is finely divided carbon. It comes from the paraffin of which the candle is made. Before the paraffin burns, it melts and then turns to a gas. This gas has hydrogen and carbon in it and, possibly, some other matter, depending on the materials of which the candle is made. The hydrogen unites with the oxygen of the air and forms water. Watch the glass carefully and a film of moisture may be seen, as well as the soot. The carbon in the paraffin is in the form of solid particles and as these particles rise through the flame they become so hot that they glow. The glowing is the source of the light. When these particles cool they collect on the glass as soot.

Some of the carbon unites with the oxygen to form carbon dioxide. This may be shown by allowing the candle to burn in a deep dish. When the flame ceases on account of the lack of oxygen, a little lime water poured into the dish will turn milky, proving the presence of carbon dioxide. If all of the carbon could be changed to carbon dioxide there would be very little light as there would then be no separate carbon particles to glow.

Kerosene lamps consist of a reservoir of kerosene at the top of which is a burner pierced with air holes. A wick extends from

the reservoir to the middle of the burner, where its height is regulated by a small thumb screw. A tall glass lamp chimney encloses the burner and the top of the wick.

Kerosene rises to the top of the wick by capillarity. When the wick is lighted, the kerosene vaporizes and combines with the oxygen in the air which flows through the holes in the burner. This oxygen combines with the hydrogen in the kerosene vapor to form water, and with the carbon to form carbon dioxide. There is always a certain amount of carbon which does not combine, and this, when heated in the flame, is the source of the light. If the lamp smokes, it is getting too much carbon, and the wick should be trimmed or turned down.

The same condition may be shown with a Bunsen burner. Light the gas and close the holes at the bottom of the burner. Soot collects as in the case of the candle and the flame gives off considerable light. If the holes at the bottom are opened the flame becomes almost colorless. This is because the holes allow the air to mix thoroughly with the gas before it begins to burn and thus the carbon has an opportunity to become oxidized.

When gas, kerosene, or gasoline is used for lighting, frequently a mantle is placed over the flame. The mantle is a small bag made of a fiber. It is soaked in a solution of a certain rare metal, thorium, and coated with something to protect it. We place this mantle on the burner and burn off the protecting coat; then the fiber burns out and leaves a network of the metal. Thorium is used because it has been found to give off the best color for lighting purposes.

In such a burner, the light comes from heating the mantle until it glows and not from the glowing of the carbon particles in the gas. In fact, if the carbon is not burned, it collects on the mantle and spoils the light. Such burners, then, must have holes at the bottom to let in enough air to make sure that the carbon is completely burned. The amounts of air and gas have to be adjusted very carefully to give the best results.

The most efficient light produced up to this time is the electric light. This has two forms, the arc light and the incandescent light. The arc light depends upon an electric current jumping a

small gap between two pieces of carbon and generating intense heat and light. Such a light is brilliant, but hard to keep adjusted. The incandescent light depends upon a thin wire heated until it glows by the passage of an electric current through it. This wire is kept in a vacuum or in a special gas within a glass bulb, as exposure to the air at high temperature would burn it up.

SUMMARY

The sun is the source of natural light. Light is one form of radiant energy.

Light waves travel from the sun at the rate of about 186,000 miles per second and radiate outward in all directions.

All objects are seen by light waves that pass through the ether from them to the eye.

A light ray is a single line of light.

A beam of light is a group of parallel rays.

Materials may be transparent, translucent, or opaque.

Color is due to the length of light waves, each color having its own length of wave.

A shadow is a dark space caused when an opaque body stops the passage of light waves.

Reflected light means light sent back from an object upon which it falls.

A beam of light when passing at an angle from one medium into another of different density becomes bent, or refracted.

The spectrum is a band of seven colors which appears when sunlight is broken up by passing through a prism.

The rainbow is a natural spectrum.

A lens is a piece of transparent glass so made that its surfaces are not parallel, and at least one is curved. There are two general classes of lenses, convex, to focus light, and concave, to diffuse it.

Nearsightedness is caused by inability of the eye to accommodate itself to distant vision, and farsightedness by inability to accommodate itself to close vision.

Fact and Thought Questions

1. What are light waves?
2. At what rate does light travel from the sun?

3. What is meant by an opaque object? A transparent object? A translucent object?
4. Describe an experiment to show the nature and cause of shadows.
5. Has the color of a house any effect on the depth of shadow it casts?
6. What is a mirror? State the effects of curved mirrors on the appearance of images.
7. What is meant by refraction of light? Give an example.
8. Describe the spectrum and state its cause.
9. What causes a rainbow?
10. State the difference between a convex lens and a concave lens.
11. Sometimes objects seen through a window appear distorted. Why?
12. Why is smoked glass used in observing an eclipse of the sun?
13. Is it true or false that a straight stick appears bent if thrust into water?
14. Is it true or false that indirect lighting causes less shadows?
15. Make a labeled drawing of the apparatus used to show that light travels in straight lines.
16. How is artificial light produced?
17. What precautions should you observe in the use and care of the eyes?
18. Over which shoulder should light come for a left-handed writer? Explain.
19. Why does an object cast a shadow in the sunlight?
20. Why does the shadow of an object vary in length at different times during the day?

Projects

1. Compare different methods of lighting, as to advantages, disadvantages and costs.
2. Study and report on sunlight in the home as affected by windows, shades, wall paper, and draperies.
3. Study a camera. (a) Make diagrams of the camera and of the human eye. (b) Label the part of the eye that corresponds to each of the following parts of the camera: (1) lens, (2) diaphragm, (3) film (plate or screen). (c) Compare the focusing structure of the eye with that of the camera.

Outdoor Observation

1. On your walks to and from school observe and record how different kinds of objects and materials absorb or reflect light.
2. Observe shadows cast by different objects, and record your findings.

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CHAPTER XIV

MAGNETISM

For centuries man knew that bars of a certain metallic ore had the power to attract iron, and that if suspended they would tend to point north and south. Only with the invention of the compass, however, was this knowledge made to serve man. Previously ship captains clung to the coast lines whenever possible, lest they lose their sense of direction. The compass made it safe to travel out of sight of land on long voyages. So the discovery of new continents was made possible.

Today the compass still directs the ocean commerce of the world, keeps airplanes on their courses, and guides travelers in safety over deserts and through forests. It has saved countless lives on land and sea.

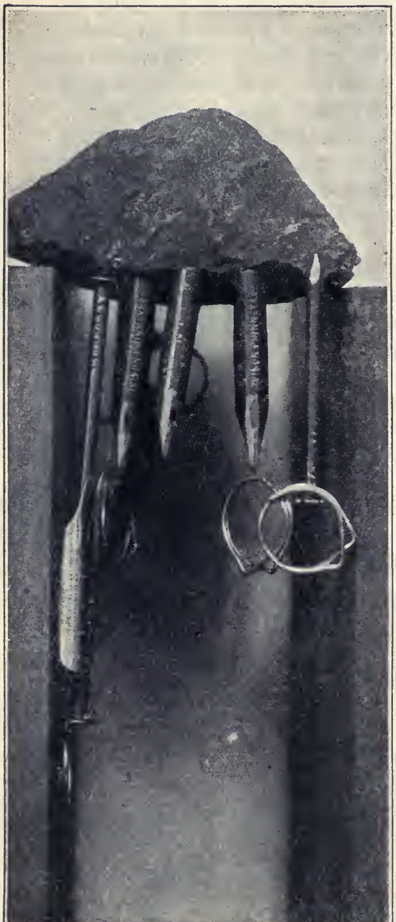
That the compass serves us at all is due to the fact that its needle moves in response to the mysterious force of the world's greatest magnet—the earth itself.

In various parts of the earth there exists an iron ore—lodestone—which has the power of attracting bits of steel and small pieces of iron. Owing to the fact that this ore was common in Magnesia, a province in southern Asia, it was called magnetite. Pieces of lodestone are natural *magnets*.

It is an interesting fact that a pocket knife blade, or other piece of steel, when rubbed on a natural magnet, becomes magnetic and remains so for a long time. Such a knife blade or piece of steel is called an artificial magnet. A piece of soft iron also may be magnetized but it retains this property for only a short time.

Properties of a Magnet.—Both natural and artificial magnets possess several special properties, among which are polarity, power to attract iron not magnetized, power to attract and repel magnetic iron, and power to give magnetism to other pieces of iron. These all show that magnetism must be a form of energy, as it tends to produce motion.

Polarity.—The *polarity* of a magnet is its tendency to point north and south when suspended. The end which points north is called the north pole of the magnet and the end which points to the south is called its south pole. Near the poles of a magnet the attractive power is much stronger than near the middle.



Brown Brothers.

THE MYSTERIOUS LODESTONE
A natural magnet.

Experiments with a Magnet.—Scatter iron filings over a bar magnet. Notice that they collect for the most part in two clusters, one near each end, or pole, of the magnet. Few, if any, collect at the middle.

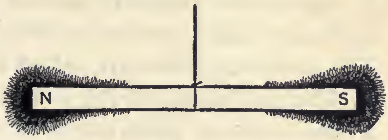
To show polarity, suspend by a silk thread a piece of magnetized steel about eight inches long, so that it balances. When it comes to rest, notice what position it assumes with reference to the points of the compass. Whirl it several times, and after each whirl let it come to rest without interference on your part. Notice whether it tends to take the same position each time.

In the same way, find out the poles of a second similar piece of magnetized steel. Bring the north (N) pole of the first magnet near the N pole of the second magnet and observe what occurs. Test the attraction of the south (S) poles for each other. Then

test the attraction of the N and S poles for each other, noting the result in each case.

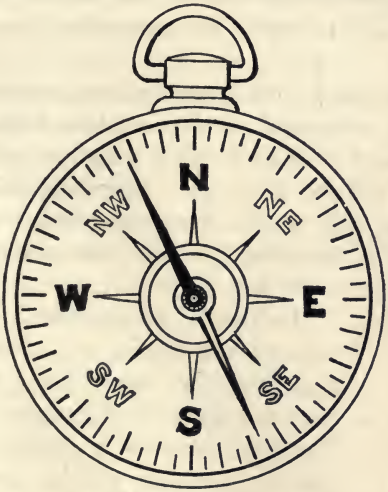
Bring into contact with each end of a bar magnet bits of string, steel, pasteboard, lead, iron and other materials. Notice which are attracted to the magnet.

Rub the blade of a pocket knife vigorously on a piece of lodestone, or on one end of a bar magnet, and afterwards touch bits of steel and other materials with it. Notice which objects touched are attracted to the blade. Touch the same objects with the blade of a knife which has not been magnetized and notice whether they are attracted to the blade. You will discover that bits of steel and iron are the only substances much attracted to magnetized objects.



MAGNETIC ATTRACTION
The positions of the iron filings show where the bar magnet's attractive force lies.

Law of Magnetic Poles.—Experiments made with two magnets of any kind or shape show that the north pole of one magnet will attract the south pole of the other magnet, and the south pole of one will attract the north pole of the other; but the north pole of the one magnet will repel the north pole of the other and the south pole of the one will repel the south pole of the other. From experiments like these, the law of magnetic poles has been formed: *Like poles repel each other and unlike poles attract each other.*



THE MAGNETIC COMPASS
It guides the traveler by means of magnetism.

The Compass.—The fact that a suspended magnet always points in a north and south direction was early discovered and led to the invention of the *compass* and of the *dipping needle,* the first of which is all important to seamen who direct

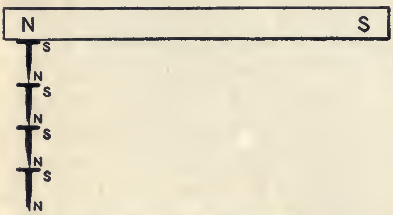
the course of ships on the ocean. The compass was the first practical use made of the power of magnetism.

The compass consists of a magnetized steel needle balanced to rotate horizontally over a round disc. This disc is marked in degrees and usually has the directions north, northeast, east, southeast, south, southwest, west, and northwest indicated upon it. The needle and disc are set in a brass frame having a glass top.

The usefulness of the compass lies in the fact that the needle tends always to point nearly north and south. The true north is determined by the observation of the sun at noon and of the North Star at night. It is thought that the first compass was made of lodestone. The name lodestone, in fact, was given magnetic ore because the word lode means path, or way, hence something that directs or leads.

Brass and glass are used in making a compass because they do not interfere with the magnetic influence of the earth. A compass box of steel or iron would destroy the magnetic power of the needle.

You can illustrate the principle of the compass in a simple way. Balance on a small cork a piece of steel wire about eight inches long and float it on water in a glass dish. Notice that the wire does not assume any definite direction. Magnetize the wire and again float it on the cork in the water and observe whether it assumes any particular direction. It will point nearly north and south.



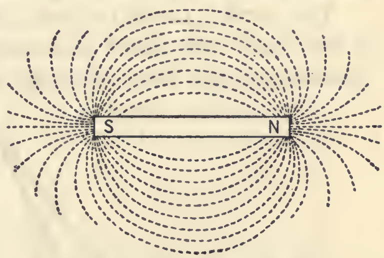
INDUCED MAGNETISM
Each tack becomes a temporary magnet.

Induced Magnetism. — Induced magnetism is a term used for what occurs when a piece of iron touches a magnet. The iron becomes a magnet. You can illustrate this by suspending a tack from a bar magnet, a second tack from the first tack, and so on. Remove the first tack from the magnet and notice what occurs. The magnetism which the tacks showed is *induced magnetism*. This may occur without contact, as may be shown by placing iron filings near one end of a short rod of soft

iron while a magnet is held near the other end. The rod will attract and hold part of the filings.

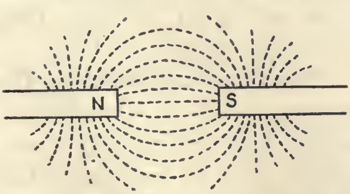
Theory of Magnetism.—It is believed that individual molecules of any magnetic substance are always magnetized. In a bar of iron that is not magnetized, the molecules are turned in all directions. In a bar that is magnetized, the molecules arrange themselves so that their like poles lie in the same direction.

Magnetic Field.—The magnetic field may be illustrated by sprinkling iron filings on a small plate of glass under which a bar magnet has been placed. By tapping the glass, the filings will arrange themselves in curved lines uniting the N and S poles of the magnet, but some lines will pass out from the poles and fail to unite with one another as shown in the illustration. The space around a magnet which is influenced by its force is known as its *magnetic field.* This field is strongest near the poles of the magnet and becomes weaker as the distance from them increases. Each line is called a *line of force.*

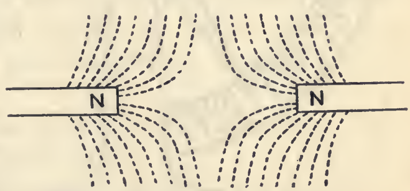


THE MAGNETIC FIELD
Notice the lines of force.

Experiment to Show Magnetic Fields.—Place two bar magnets in a straight line so that the N pole of one is a short distance from the S pole of the other. Cover the magnets with a



LINES OF FORCE FROM UNLIKE POLES OF TWO MAGNETS



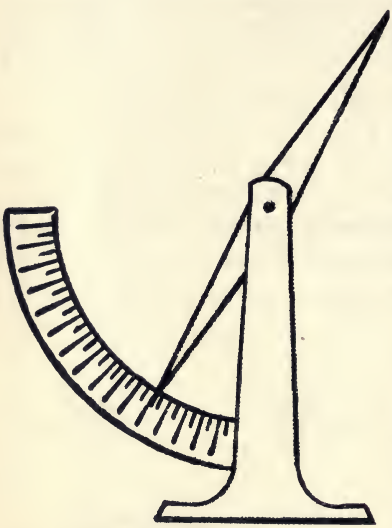
LINES OF FORCE FROM LIKE POLES OF TWO MAGNETS

plate of glass and scatter iron filings on it. Tap the glass. Filings will arrange themselves along lines of force from the two poles mentioned. If one magnet is reversed so that the N poles of the two magnets are near each other the filings will show that the

lines of force coming from these poles are repelled, or driven apart. These results agree with the law of magnetic poles.

The Earth as a Magnet.—The earth is a magnet of great size with a north pole and a south pole. One of its magnetic poles lies near the north pole of the earth and the other near the south pole of the earth. The magnetic poles, however, are not the same as the geographical poles. Dr. William Gilbert, in the year 1600, discovered that the earth is a magnet and that the magnetic poles are not the same as the geographical poles. This discovery led to the explanation of a fact which had troubled mariners in early days, that the compass did not always point exactly north.

The earth's north magnetic pole, which is of the same nature as the south pole of all other magnets, lies in the region north of Hudson bay and west of Baffin bay. It is not a fixed point, but is believed to cover a large area. Within the Antarctic circle, between New Zealand and the south pole, there is a similar region known as the south magnetic pole. This is of the same nature as the north pole of all other magnets. The cause for the magnetism of the earth is not known. It is believed to be some condition existing deep below the earth's surface.



THE DIPPING NEEDLE
Horizontal at the equator; vertical at the earth's magnetic poles.

The Dipping Needle.—The *dipping needle* is a magnetized needle balanced to rotate vertically. It is an interesting fact that the north end of the dipping needle dips more and more as the instrument is carried north from the equator until a point is reached where it stands vertical. The needle is then over the earth's north magnetic pole. If carried south of the equator, the south end of the needle dips

until the needle becomes vertical over the south magnetic pole. The angle the needle makes with a horizontal line is called the dip of the needle. The dipping needle is also used to locate magnetite, a valuable iron ore.

Experiment to Illustrate the Dipping Needle.—The action of the dipping needle may be illustrated with two steel knitting needles, a cork, a large pin and two glass cups. Thrust the needles half their length through the cork, at right angles to each other. Set the cups a short distance apart. Use one needle as an axis by resting its ends on the cups in such a way that the other needle balances and points north and south. If the other needle does not balance horizontally stick the pin in the cork so as to make it balance.

Remove the device from the cups and magnetize the balanced needle. Replace the device in the same position. Does the magnetized needle remain horizontal? If properly adjusted, the N pole of the magnetized needle will dip and the needle will make an angle with the horizontal.

SUMMARY

There exists in some parts of the earth an ore that has the power of attracting bits of steel and iron. This ore, which we call lodestone, is a natural magnet.

An artificial magnet may be made by rubbing a piece of steel with a natural magnet or with another artificial magnet.

A magnet possesses certain properties, such as polarity, power to attract iron not magnetized, power to attract and repel magnetic iron, and power to give magnetism to other pieces of iron.

The polarity of a magnet is its tendency, when suspended, to point toward the north and south poles.

The compass is an instrument used to aid in finding directions. Its needle points north and south.

Induced magnetism is the magnetism caused in a piece of iron when it comes in contact with a magnet.

It is believed that when a substance is magnetized its molecules arrange themselves with like poles lying in the same direction.

The magnetic field is the space around a magnet which is influenced by its force.

The earth is a magnet of great size having a north and a south magnetic pole.

A dipping needle is a magnetized needle accurately balanced on a horizontal axis. It is used to locate the earth's magnetic poles, or to locate beds of magnetic ore.

Fact and Thought Questions

1. What is a natural magnet? An artificial magnet?
2. Name some materials that are attracted by a magnet.
3. Give several properties of a magnet.
4. What is the largest magnet you have seen?
5. How could you use a magnet to find a needle lost in a dark spot?
6. Will a magnet pick up a tack from the bottom of a pail of water?
7. State the law of magnetic poles.
8. Describe the magnetic compass.
9. Why is a magnetic compass uncertain and difficult to use on a steel ship?
10. What is induced magnetism?
11. What is meant by a magnetic field?
12. What are the properties of the dipping needle?
13. Is it always absolutely safe to depend on a compass? Why?

Projects

1. Make an artificial magnet. Experiment with its lifting power.
2. Make a dipping needle. Make a labeled drawing of it.

Outdoor Observation

1. Take a walk across country, or through a patch of woods, trying to hold a straight course by a pocket compass. Observe and record difficulties in doing this.
2. Carry a pocket compass through a busy business street. Observe if it is affected at all. Record your observations.

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CHAPTER XV

ELECTRICITY

Strange as it may seem, a scientist does not have to know all about a form of energy to use it. If he discovers *how it acts* or *how it is produced* he can apply this knowledge in ways to render great service to mankind. Electricity is a striking illustration.

Each of us can name ways in which electricity benefits us. We know it as one of the most useful forms of energy. Yet no scientist knows what it is. In a way it is as mysterious to us as it was to the Greeks who began to wonder about it many centuries ago.

We can easily produce electricity. We can make it by stroking a cat's fur, or by combing our hair, or by placing certain metal strips in a jar of acid and water, or we can transform the energy of water into electricity. The scientist knows how electricity behaves, how to measure it, how to control it, and how to transport it to distant points where it will be useful. We should all become better acquainted with this great force that is playing a larger part in our lives each day. We are living in an electric age.

The exact nature of electricity is not fully known. That it is a form of energy no one doubts. Like water and air, it will flow and exert pressure under the proper conditions. Upon these two properties depends its great value in doing work for the benefit of man. Although from the remotest ages electricity in the form of lightning and the northern lights has been observed by man with interest and wonder, it is only in comparatively recent times that he has learned how to harness electricity and make it serve him in many varied fields.

Static Electricity.—Static means stationary. *Static* electricity means electricity held or confined in comparatively close limits. Unconfined electricity is *current,* or flowing, electricity. Thales, a Greek, noticed that when amber was rubbed it had the property of attracting to itself light bodies, such as dry bits of paper and pith balls. This attracting force of static electricity differs from

magnetism, for the magnet will not attract paper. It remained for William Gilbert, physician to her majesty Queen Elizabeth of England, to show that other objects possess the same power of attraction. He it was who coined the word electricity from the Greek word elektron, meaning amber.

Substances that attract other substances as amber does are said to be *electrically charged.* Glass stroked with silk, and sealing wax rubbed with woolen cloth have been used for centuries, and still are used, to illustrate this phenomenon of static electricity in electrically charged substances. Many other materials will become electrically charged under favorable conditions.

Experiments to Illustrate Static Electricity.—Rub a stick of sealing wax with fur or with a dry, warm, woolen cloth. Then bring the wax near small feathers. Notice what happens to the feathers and give the reason.

Rub a perfectly dry and warm tumbler with a silk handkerchief, also dry and warm. Tear up scraps of paper and hold the tumbler over them. Notice what happens to the scraps of paper and give the reason.

Cut up, or file, two or three corks into small bits. Put the bits on the middle of a sheet of paper on each end of which are small wooden blocks of equal height. Place a warm pane of glass across the wooden blocks over the cork bits. Rub the upper part of the glass with a warm, dry silk handkerchief. Notice what happens to the bits of cork and give the reason.

Rub a warm, dry piece of flannel forcibly over a warm, dry fountain pen. Then hold the pen over scraps of paper or over small feathers. Notice what happens and give the reason.

Kinds of Electrification.—There are two kinds of electrification, named by Benjamin Franklin in the 18th century, *positive* and *negative.* The experiment of rubbing glass with silk developed on the glass a charge of positive electricity, and on the silk a negative charge. The experiment with the sealing wax and the fur developed a negative charge on the sealing wax and a positive charge on the fur. The electrical charges developed on these objects by friction sustain a relation to each other quite similar to that of the poles of magnets, in which unlike

poles attract and like poles repel each other. There is also a law quite similar to that in regard to magnets: *Unlike electrical charges attract and like charges repel each other.*

The Electroscope.—The electroscope is an instrument for finding out whether or not an object is electrically charged. It usually consists of a metal rod passed through the stopper of a glass jar and having a round piece of metal on the upper end and a hook on the lower end. To this hook are attached two equal-sized strips of gold leaf which hang below the center of the jar. When an object is brought in contact with the metal top, the strips of gold leaf will spread apart if the object is charged, but will not move if it is not charged.

A simple electroscope may be made by suspending a small pith ball from a standard by means of a silk thread. The pith ball may then be charged by touching it with a charged amber rod. When the charged amber is brought near it the second time, since it has the same kind of a charge as the pith ball, it will repel the ball. Two pith balls may be suspended and used like the two gold leaves in the experiment above. Franklin used two linen threads suspended in this manner to detect charges of electricity.

A SIMPLE ELECTROSCOPE

It shows whether or not an object is electrically charged.

Conductors and Insulators.—Substances through which electric charges pass readily are spoken of as *conductors*. Substances through which electric charges will not pass are called *insulators*. Among the good conductors are such metals as silver, copper, and aluminum. While pure water is a non-conductor, the addition of a moderate amount of any acid or salt makes it a good conductor. Among the best insulators are rubber, glass, porcelain, wood, and dry air. You have probably noticed that iron and copper wire are largely used in electrical devices and that glass and porcelain are also used. Can you suggest reasons for all four?

Potential.—*Potential* is an important term in electricity. The potential of any point in an electrical circuit is the amount

of electrical pressure at that point. An electric current is produced by a difference in the potential, or amount of electrical charges, at the two ends of a conductor. The current flows from the point of the greater potential to that of the lesser, much as water flows from a higher to a lower level.

The Leyden Jar.—A *condenser* is a device for accumulating and holding a large charge of electricity in a small space. Condensers are used in laboratories, and in a practical way in radio sets. The principle of the condenser is illustrated by the Leyden jar, named after the city in Holland where it was first used. The jar is made of glass and has a coat of tin foil, both inside and outside, up to about two-thirds of its height. A brass rod, having a knob at one end and a metal chain at the other, is passed through the stopper of the jar in such a way as to leave the knob outside the jar and the chain inside, in contact with the inside tin foil coating. There are two conductors, the tin foil on the inside and the tin foil on the outside, separated by the insulating glass wall.

THE LEYDEN JAR
It stores static electricity. Used to illustrate lightning.

The condenser is charged by connecting the outer tin foil with the earth by means of a wire or other conductor, or by direct contact, and then giving the inside coating a charge of positive or negative electricity. The inside charge attracts electricity of the opposite kind from the ground and holds it to the outer coating, and repels electricity of the same kind.

A Leyden jar may be discharged by placing one end of a bow-shaped metal rod, having an insulated handle at the middle, in contact with the outside covering, while the other end is brought near the knob of the jar. A spark will pass through the air between the end of the rod and the knob, producing a crackling noise. This illustrates how lightning is produced.

Lightning.—Lightning is the discharge between two clouds bearing unlike electrical charges, or between clouds and oppo-

sitely charged objects on the earth. The loud noise called thunder, which follows lightning, is similar to the crackling noise heard at the time of the discharge of the Leyden jar, except that it is much louder. It continues to rumble because the sound is reflected by the clouds.

In 1752 Benjamin Franklin proved that lightning is an electrical discharge. He built a kite with a pointed wire at the top and flew it during a thunderstorm. At the lower end of the kite string he tied a piece of silk ribbon, a non-conductor, and where

U. S. Weather Bureau.

LIGHTNING
Electricity out of control.

ribbon and string met he fastened a metal key. The wet kite string was a conductor, and Franklin, putting his knuckle near the key, was enabled to draw electric sparks from the key. There was a difference in potential between the clouds and the ground. This caused electricity to pass from the clouds through the kite, the kite string, the key, and through Franklin to the ground.

Electron Theory.—Scientists have formulated a theory of electricity known as the *electron theory,* which has been quite

generally accepted. It assumes that all atoms are made up of minute particles of electricity, both positive and negative. If you could observe an atom, you would see the positive particles, called *protons,* forming the center, or *nucleus,* about which the negative particles, called *electrons,* revolve much as the planets revolve around the sun.

Here is a simple illustration of this theory. If we rub a glass tumbler with a piece of silk, the silk is supposed to rub electrons from the glass, leaving more positive electricity than negative. The glass is thus left positively charged. The silk, having picked up negative electrons from the glass, has become negatively charged. This is like rubbing one's wet hands with a towel. The towel picks up moisture from the hands and becomes wet while the hands become dry.

Current Electricity.—It has been stated that electricity, like water and gas, will flow and exert pressure under suitable conditions. When it flows it is called current electricity. To be of practical use the current must always be flowing. To accomplish this there must be a difference in potential, or amount of electrical charge, which must constantly be maintained. How to maintain it is the problem.

The Electric Cell.—The electric cell is the result of the discovery by two Italians, Volta and Galvani, that electric charges can be produced by chemical action. This is why the electric cell is sometimes referred to as the Voltaic cell, and sometimes as the Galvanic cell. Volta experimented with a cell consisting of a strip of zinc and a strip of copper placed opposite each other, but not in contact, in a glass of water to which a few drops of acid had been added. He found out that when the tops of the zinc and copper strips were joined with a wire, there was a continuous flow of electricity through the wire from the copper to the zinc. Chemical energy was thus changed to electrical energy.

The Circuit.—The *circuit* is the course the current takes in its complete passage from the starting point back to the same point. Not only must there be an unbroken path through the wire between the copper and the zinc plates, but there must also be a similar path through the liquid that separates the plates;

otherwise there will be no circuit. A small electric charge occurs as a chemical reaction takes place between the zinc and the acid, which releases energy that drives the current through the whole circuit.

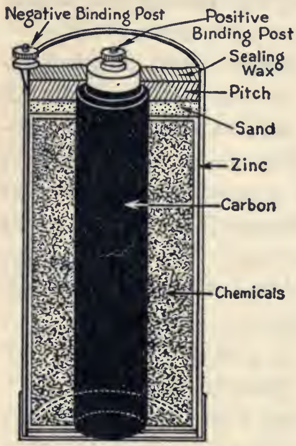
Kinds of Electric Cells.—This change from chemical to electrical energy may be brought about by placing two kinds of material, usually strips of metal, or one metal strip and one carbon strip, in a solution of some such substance as sal ammoniac or sulphuric acid. If the two strips of material dissolve in the solution at different rates, we may connect the tops of these materials with a wire and thus get a current. We call such an outfit a *cell*. A *battery* is composed of several cells connected together in a group to give greater strength.

The Simple Cell.—Pour some water in a glass jar and add a small amount of sulphuric acid. Then place a narrow strip of zinc and a strip of copper in the jar, making sure that they do not touch each other. Notice that many bubbles rise from the zinc and almost none from the copper. This shows that the chemical action is not the same on the two. Connect the tops of these metals with a wire. Notice that the bubbles of gas appear on the copper, instead of on the zinc. This is not because the greater chemical action is on the copper, but because a complete path has been formed by which the electric current can travel back to its starting point. The bubbles of gas are really being formed on the zinc as before, but they pass through the sulphuric acid and water to the copper plate. When doing this they are so small that they cannot be seen. We can see them on the copper plate because they collect into large bubbles. Such a cell is known as a *simple* cell and is the form that Volta, the discoverer of this method of forming electricity, used in his study.

There are many different types of these cells for various uses. About the only ones we see in common use, however, are the dry cell and the storage cell.

The Dry Cell.—The dry cell, very commonly used in doorbell circuits, consists of a zinc cylinder, through the center of which runs a carbon rod. Around the rod is packed a mixture of certain chemicals. The cell is not really dry, for the chemicals are

moistened and sealed airtight. The chemicals act on the zinc much as the acid did in the simple cell. If the cell is connected in a circuit, a powerful current will flow for a short time from the binding post at the top of the carbon rod, through the circuit, to the binding post at the top of the zinc cylinder. Such cells are of little value for furnishing a steady current for a long time.



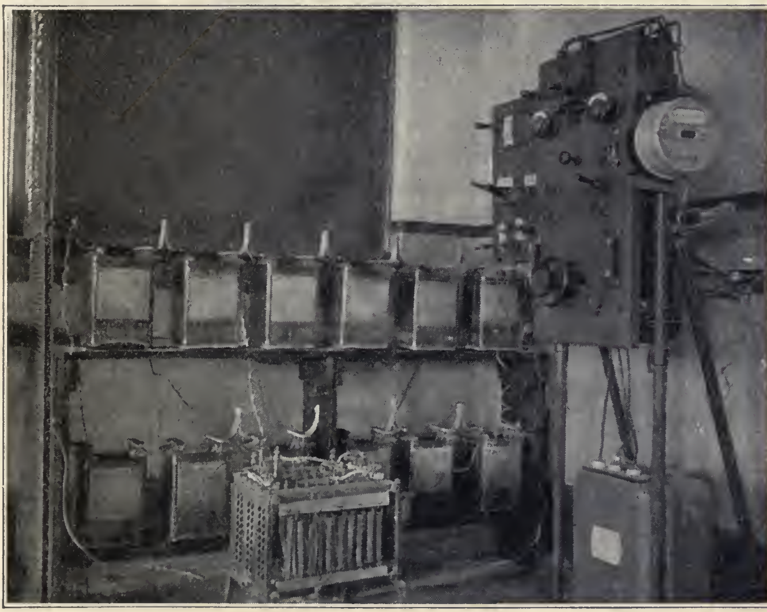
A Cross Section of a Dry Cell

The Storage Cell.—The storage cell is a device for storing up electrical energy in the form of chemical energy. By passing a small electric current through the cell for a long period, enough energy is stored in the cell to give off a powerful current for a short period. Storage cells usually are built or connected in a group called a *battery*.

Some electric power plants have storage batteries in which energy is stored from their dynamos during periods of low demand for current. These batteries are then drawn on to add to the supply of current at periods of high demand. Storage batteries are used in automobiles for starting and lighting, in radio, and in country homes for private lighting plants.

A storage cell can be prepared by placing two strips of lead in sulphuric acid that has been diluted by adding to it about five times its volume of water. These strips of lead, when connected up as in the simple cell, will show no electric current because the two plates are of the same kind of material and, the action of the sulphuric acid on the two being the same, no potential difference is set up by the chemical action. If we pass an electric current through this cell by connecting it to a dynamo or to a group of cells, we notice that the colors of the two strips of lead change. In a short time one of them turns to a dark red and the other becomes a darker gray. One of these plates has been changed over to a new substance called lead peroxide, while the other has become porous. This process is called *charging*.

After charging for some time, disconnect the charging outfit and then connect up the cell with a door bell. You can get a weak current from it for a short time. Each time you charge it the result becomes better and after a few chargings you are able to obtain a strong current.



CHARGING A STORAGE BATTERY
It stores electrical energy as chemical energy. This chemical energy produces in turn a powerful electric current.

Unit Measures of Electricity.—Just as we have the gallon with which to measure the flow of water, and the pound with which to measure its pressure, so we have standard units to measure electricity. These measures are the ampere, the ohm, the volt and the watt.

The Ampere.—The amount of electricity flowing through a conductor per second is measured by the *ampere.* For example, an ordinary electric bell requires a flow of $\frac{1}{10}$ amperes. Amount of current is measured by an instrument called an ammeter

(ampere meter) having a scale marked in amperes. Notice the action of the ammeter on any automobile when its lights are turned on or off.

The Ohm.—An electric current meets with resistance in passing through any conductor. The length, size and material of the conductor affect the amount of resistance. Consequently the electrician must make allowance for resistance in planning all electrical work. The unit for measuring resistance is the *ohm.* One ohm equals the resistance offered by 157 feet of number 18 copper wire, such as is used in doorbell wiring.

The Volt.—To set anything in motion, force or pressure must be applied. This is as true of electric currents as of solids. To keep an electric current flowing between two points in a circuit there must be a difference in potential, or amount of electrical charge, at the two points to cause pressure. This pressure is called *electromotive force.* It is measured in *volts* by an instrument called a *voltmeter.* A volt is the electromotive force necessary to cause a current of one ampere against a resistance of one ohm. The ordinary voltage in the wiring of a house is 110 volts.

The Watt.—The amount of work an electric current can do is measured by the *watt.* The number of amperes of current multiplied by the number of volts gives the number of watts. Electric light bulbs are marked in watts, to show the power of the light produced. Bulbs of 40 watt capacity are most commonly used in homes.

Power for running machinery and all lighting plants is often measured in *kilowatt* hours. A kilowatt hour represents the work of 1000 watts for one hour.

SUMMARY

The exact nature of electricity is not known. Under suitable conditions electricity will flow and exert pressure, or force.

Static electricity is confined electricity produced by friction or similar means.

There are two kinds of electric charges, positive and negative.

The electroscope is an instrument for finding out whether or not an object is electrically charged.

A conductor is a substance through which an electric charge passes readily. An insulator is a substance through which an electric charge will not pass.

A condenser is a device by means of which electrical charges are accumulated. A Leyden jar is a condenser.

Lightning is a discharge between two clouds bearing unlike electrical charges, or between charged clouds and oppositely charged objects on the earth.

The electron theory assumes that the atoms of all substances contain electrons of negative electricity and protons of positive electricity.

Current electricity means flowing electricity.

An electric cell is a device for the production of electricity by chemical action.

The circuit is the course an electric current takes in its complete passage from some point back to the same point.

Dry cells differ from wet cells in having the chemicals in the form of a moist paste instead of in a liquid.

Storage cells have plates of lead. Such cells are used to store electric energy from an electric current, in the form of chemical energy.

Electrical resistance is the term applied to the amount of difficulty a current has in passing over conductors and through instruments.

Ohms, volts, amperes and watts are units used in measuring electricity.

Fact and Thought Questions

1. Upon what properties does electricity depend for its value in doing work?
2. Give two simple experiments that illustrate the action of static electricity.
3. Describe the electroscope and state its purpose.
4. State the difference between a conductor and an insulator and give examples of each.
5. Define potential.
6. Describe the Leyden jar.
7. State the electron theory.
8. Describe an electric cell.

9. What is meant by an electric current? What must be considered in measuring its effect?
10. Why do lightning rods extend into the ground? Why should the ground be moist?
11. Describe a storage cell.
12. Would you use a cell if you needed a great amount of electricity?
13. Name several common uses of electric cells or batteries.
14. What kind of cell may be used for a doorbell? For an automobile?
15. For what are each of the following used: Ohm, volt, ampere, watt?
16. Is it true or false that a modern steel building does not need lightning rods?

Projects

1. Make an electroscope and test it.
2. Make a simple electric cell.
3. Secure an old automobile battery, take it apart and examine its construction. Make labeled sketches showing the construction.

Outdoor Observation

1. Record your observations of lightning during a night thunderstorm. Study the effects of a lightning stroke on a tree, if possible.
2. During a walk about town observe and record different uses of electricity.

References

Practical Electricity for Beginners.......................... *Willoughby*
Romance of Modern Electricity................................ *Gibson*

CHAPTER XVI

USES OF ELECTROMAGNETS

We are all familiar with small magnets that attract iron filings and mysteriously support strings of tacks, and we have laughed at magnetic toys that perform strange antics. Few realize, however, the useful part magnetic force plays in our lives when it works hand in hand with electricity.

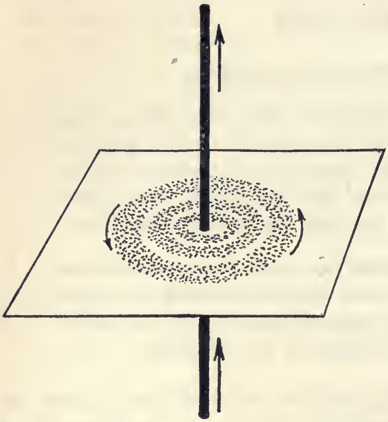
Today electricity and magnetism have been put in double harness. They drive many of our household appliances, give us our telephones and telegraphs, run our street cars and drive machinery in many of our factories.

Electricity and magnetism are not the same although they are closely related. Their relationship was not understood or explained until the early part of the 19th century (1819).

A Danish physicist, Oersted by name, noticed that a compass needle was more or less affected when brought near a wire through which a current of electricity was flowing. He noticed that when a wire connecting the poles of an electric cell was held over a magnetic needle, the north pole of the needle was deflected toward the west if the current in the wire was flowing from south to north, and towards the east if the current flowed from north to south. This led to the discovery of the magnetic effect of electric currents. Oersted showed clearly, by experiment, that every electric current is surrounded by magnetic force which influences the direction of any magnetic needle near which the current passes.

Experiment to Show the Effect of an Electric Current on a Magnetic Needle.—Sprinkle iron filings on a piece of cardboard about a foot square, through the center of which a wire connected with a powerful battery has been passed. A storage battery or several dry cells connected in a battery are needed to show good results. Turn on the current and tap the edge of the cardboard gently. Notice what happens to the iron filings. Place a small compass at different positions on the cardboard and

observe the effect of the electric current on the needle. It will indicate the direction of the magnetic lines of force.

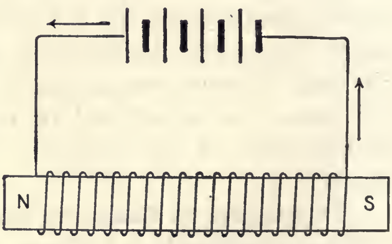


MAGNETIC FIELD AROUND A CURRENT-BEARING WIRE

Like a magnet, an electric current has lines of force. The iron filings show a cross section of the magnetic field.

In 1831 two scientists, Joseph Henry, an American, and Michael Faraday, an Englishman, working separately, discovered that when a magnet is moved inside of a coil of wire a current of electricity is started in the wire. This led to the development of machines to generate electricity, in which magnets were made to move within coils of wire or coils of wire to move within magnets. This was the beginning of the modern dynamo.

The Electromagnet.— The material part of an electromagnet is merely a piece of soft iron encircled by a coil of insulated wire. One can be made by placing an iron nail within a coil of insulated wire. Such a device, however, does not act as a magnet until a current of electricity is flowing through the coil. The coil is called a *helix*. When energized by an electric current, the nail gains the properties of a bar magnet; that is, it has a north magnetic pole at one end and a south magnetic pole at the other end. This may readily be shown by testing with a magnetic needle.



A SIMPLE ELECTROMAGNET

A battery of electric cells, indicated by the vertical lines at the top, supplies a current of electricity. This current, in passing through the coil of wire, makes a temporary magnet of the bar of iron.

An electromagnet is an essential part of almost all electrical machines in common use, such as the dynamo and the motor.

Its power depends on two factors, the number of turns of wire in the helix and the strength of the current.

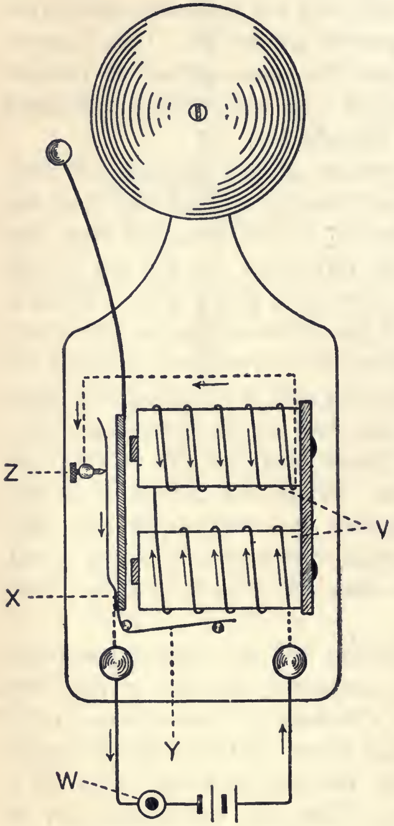
Although electromagnets are manufactured in different shapes, with reference to the use for which they are intended, the horseshoe shape well illustrates their general properties. This shape is considered especially useful because the same amount of current through the same number of turns of wire will produce a stronger magnet in this shape than in a straight bar.

A horseshoe electromagnet consists of two parallel soft iron bars, the cores, joined across their tops by a third iron bar, the yoke. Around each core is wound a coil of insulated wire, the two coils being wound in opposite directions and the top of one connected to the bottom of the other by a single wire. When a current is run through these coils the difference in the directions of winding produces opposite effects in the two cores, making the free end of one a N. pole and the free end of the other a S. pole.

In places where much iron and steel are handled, giant electromagnets are often used on cranes and derricks in place of hooks or other fastening devices. When the current is turned on, these magnets cling to any iron or steel object that they touch. So powerful is the attraction of some electromagnets that pieces of iron or steel of more than 150 tons have been lifted by them.

The Electric Bell.—The electric bell is a familiar application of electricity. A circuit is necessary in order to have the bell ring. This circuit requires a battery of two or more cells, a bell, a push button, connecting wires, and an electromagnet. Across the ends of the magnet, but not touching them, is a soft iron bar called an *armature*. This armature forms part of the circuit. When the button is pressed the circuit is completed, and a current of electricity immediately passes from the battery through the coils of the magnet. This causes magnetism, which draws the armature toward the magnet, and the hammer attached to the armature strikes the bell. When the armature moves, the circuit is broken, and the current no longer reaches the magnet. The magnet then ceases to attract the armature, which immediately springs back and again completes the circuit.

This movement of the armature, due to the alternate closing and opening of the circuit, causes the strokes on the bell to be repeated rapidly as long as the button is pressed.



An Electric Bell

Pressing the push button, W, completes the circuit and causes a current from the battery to operate the electromagnet, V. The electromagnet attracts the armature, X, moving the hammer against the bell. This breaks the circuit at the screw, Z. Immediately the spring Y pulls the armature back, again closing the circuit. This action continues as long as the button is pressed.

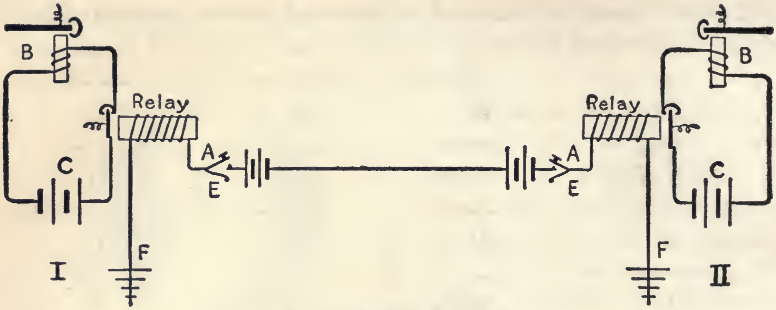
When a doorbell fails to respond to the push of the button it usually will be found that the battery is exhausted and must be replaced. If this is not the case, the cause probably lies in some break in the connections.

The Telegraph.—Another well known application of the electromagnet is the *telegraph.* The word is derived from the Greek stems graph, meaning write, and tele, meaning afar off. The telegraph, then, means an instrument which writes far away. It was invented by S. F. B. Morse, an American, in 1832. He demonstrated the fact that messages could be sent over a wire between widely separated places by means of a series of clicks representing different letters of the alphabet. Each click made at one end of the line caused a corresponding click at the other end, which was indicated on a moving slip of paper by a series of dots and dashes. The dash represented a longer time between the clicks than the dot. By combinations of dots and dashes all the letters of the alphabet were represented. The following table shows

the combinations of dots and dashes used in the American Morse code to represent letters:

-—	—---	-- -	—--
A	B	C	D
-	-—-	——-	----
E	F	G	H
--	—-—-	—-—	——
I	J	K	L
——	—-	- -	-----
M	N	O	P
--—-	- --	---	—
Q	R	S	T
--—	---—	-——	-—--
U	V	W	X
-- --	--- -	-——-	--—--
Y	Z	1	2
---—-	----—	———	------
3	4	5	6
——--	—----	—--—	———
7	8	9	0

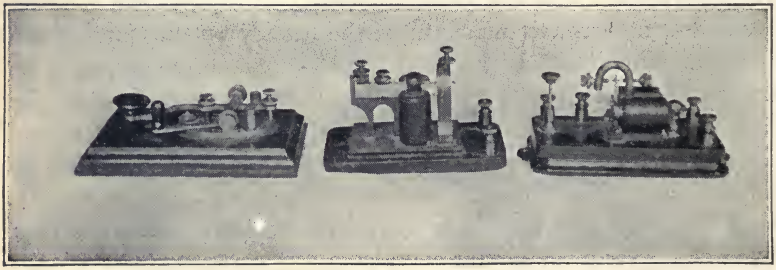
A simple telegraph can be made from a battery, a sending key, a sounder, and a connecting wire. A second wire is not necessary to complete the circuit if the battery on the sending end and the sounder on the receiving end are connected by wires to the ground, which acts as a conductor. When the key of the sending set is pressed, the circuit is completed and a current of electricity at once flows from the battery, through the wire, to the sounder. The sounder consists of an upright electromagnet near the ends of which is a soft iron armature connected to a brass rod. With the circuit completed, the electromagnet attracts the armature downward, pulling the brass rod against a screw, making a click. When the key is released and the circuit broken, the armature is pulled upward by a spring and the brass rod clicks against another screw. In this way every movement of the key produces a click from the sounder. By varying the intervals between clicks, the dots and dashes of the Morse code can be given.



A TELEGRAPH CIRCUIT

I and II represent two telegraph sets connected by a wire. If it is desired to send a message from II to I, the switch E of set I is closed. Then when key A in set II is pressed it completes the main circuit of the two sets and allows an electric current to flow around the coil of the electromagnet in the relay of set I and into the ground at F. This current operates the electromagnet in relay I, causing it to attract the armature located at its left, thus completing the circuit of set I. This allows a powerful current from battery C to flow through the circuit of set I and operate the electromagnet in sounder B, attracting the sounder armature at the top. When the switch of set II is closed and the key of set I is pressed, the process is reversed. In this way every movement of the key of one set causes a corresponding movement in the sounder of the other set.

The Relay.—When the current is not strong enough to work a distant sounder, a *relay* is used. This relay consists of a light armature controlled by a powerful electromagnet, and so delicately adjusted that it responds to even a very weak current.



TELEGRAPH INSTRUMENTS

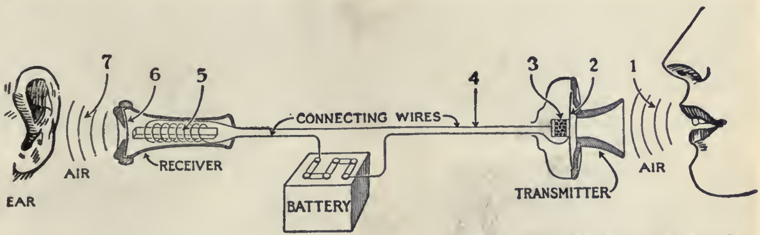
Key. **Sounder.** **Relay.**

When the key in the main circuit is pressed, the weak current causes the electromagnet in the relay to draw its armature into contact with a fixed screw. This closes a local circuit and allows a powerful local battery to operate the sounder. Thus, by the

relay, a distant key causes a sounder to make a series of loud clicks.

The Telephone.—The word *telephone* is derived from the Greek stems phon, meaning sound, and tele, meaning afar off. The telephone, then, is an instrument which carries sound far away. The telephone was invented by Alexander Graham Bell, in 1876, demonstrating to the world that the sound of a human voice could be carried by electricity to far-away places and heard distinctly.

The important parts of a telephone circuit are the *transmitter*, the *receiver*, the connecting wires, and a source of electricity. The transmitter consists of a mouthpiece, a vibrating diaphragm, and, touching the diaphragm, a circular box about the diameter



American Telephone and Telegraph Co.

A SIMPLE TELEPHONE CIRCUIT

1. Sound waves in air. 2. Diaphragm. 3. Sound box. 4. Connecting wire. 5. Electromagnet. 6. Diaphragm. 7. Sound waves in air.

of a penny. In the box are loosely-packed coarse grains of carbon. The top and the bottom of the box are made of conducting material and are connected with wires extending to the receiver. We know, from observation of bells, drums, and harp strings, that vibrating bodies are the source of sound waves which travel through the air. When the sound waves caused by the vibration of the vocal cords in our throats strike the diaphragm of the telephone transmitter, they cause it to move to and fro, and the carbon grains in the box are first pressed closer together and then loosened. The firmness or looseness of the contact between these grains varies the resistance in the circuit. This, in turn, varies the electric current which is being sent through the circuit by a battery which forms a part of the circuit.

A telephone receiver usually consists of a steel U-shaped magnet, on each arm of which is a coil of many turns of fine wire. This wire is connected to those extending to the transmitter. Across the ends of the magnet there is supported a thin disc of soft iron called the diaphragm. This diaphragm is quite close to the ends of the magnet, but does not touch them. The magnet and diaphragm are housed in a hard rubber case.

When the increasing and decreasing current from the transmitter flows through the coils of the receiver, the magnet in the receiver becomes stronger and weaker accordingly. The soft iron diaphragm of the receiver is made to vibrate by the variation in the strength of the magnet. The vibration of this

American Telephone and Telegraph Co.

VIBRATIONS CAUSED BY SOUND WAVES

diaphragm sets up sound waves like those which cause the transmitter diaphragm to vibrate.

The telephone wires do not carry sound, but they carry a varying electric current. At the speaking end of the telephone there is sound in the form of sound waves from the voice. These sound waves cause a vibration of the diaphragm of the transmitter, which in turn causes variations in the current passing in the circuit to the listening end. This varying current causes the diaphragm of the receiver to vibrate, and produces sound waves in the air, thus reproducing the words of the speaker.

The telephone is an excellent illustration of the transformation of energy. At the speaking end of the line the energy of motion is transformed into electrical energy, and at the

listening end electrical energy is transformed back into energy of motion.

The Induced Current.—Owing partly to the great expense involved in using zinc as a fuel in generating large quantities of electricity, we do not depend on batteries to provide electric currents in large industrial plants. There is a cheaper and better way—the use of induced currents, caused by moving a coil of insulated wire near a magnet. When the coil of wire is connected into a circuit the current flows around the circuit. A current generated in this way is known as an *induced* current.

Experiment to Show Induced Current.—The following experiment illustrates the induced current by showing the possibility of causing a momentary electric current without a battery. The materials needed are a *galvanometer,* to measure the current, a coil of many turns of fine insulated copper wire, and a bar magnet. Connect the ends of the coil to the galvanometer and then insert into the coil the N pole of the magnet. Notice that the needle of the galvanometer is deflected as the magnet enters and leaves the coil. Repeat the process, using the S pole of the magnet, and observe what occurs. These observations lead to the conclusion that a magnet moved near a conducting coil induces a current in the conductor.

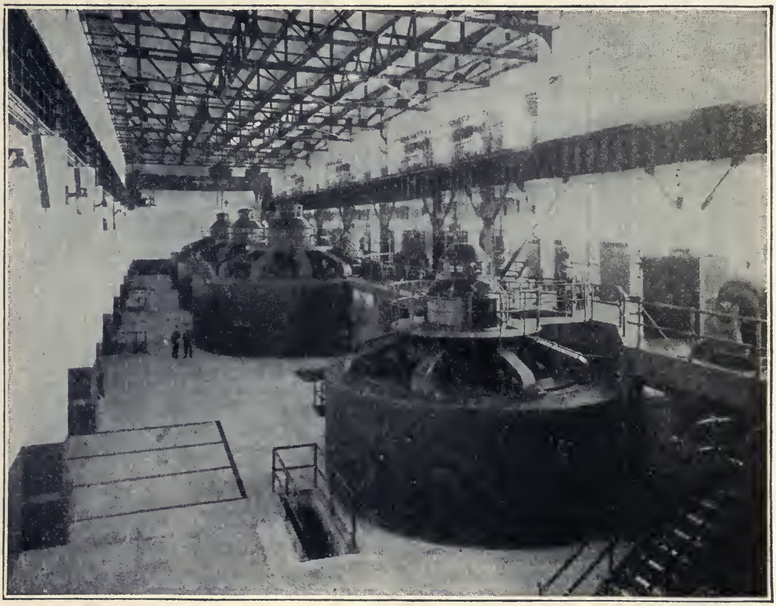
The Dynamo.—The dynamo is a machine which is used to change mechanical energy into electrical energy. In its simplest form it is merely a coil of insulated wire electrified by being moved within the magnetic field of a magnet.

The important parts of a practical dynamo consist of the magnets, the armature, the commutator and the brushes. The magnets are U-shaped and are used to produce the magnetic field. In consequence, they are called field magnets. The armature consists of a coil or coils of wire wound around a soft iron core. The armature rotates in such a way that the coil of wire moves in one direction through the magnetic field for one-half a revolution and then in the opposite direction. Hence the current formed in the coil is an *alternating* current—flowing first in one direction and then in the opposite direction. Most of our houses are lighted by alternating currents.

The commutator is an attachment which changes this alternating current into a *direct* current which flows in one direction.

The brushes are metal or carbon blocks which, by contact with the armature, take the current from the dynamo and carry it to the wires in the outside circuit.

It will be helpful to study a dynamo in some electric power station, or to examine the parts of the generator in an automobile.



Niagara Falls Power Co.

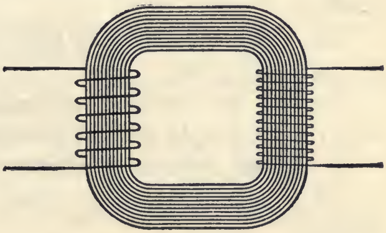
GIANT DYNAMOS AT NIAGARA FALLS

They transform the energy of the falling water into electric energy.

Source of Energy of the Dynamo.—It should not be forgotten that the dynamo does not make energy. It only transforms the energy of motion into electrical energy. It illustrates well the principle of the transformation of energy. A steam engine or a gas engine or a turbine is necessary to drive the dynamo, and each of these is dependent on some source for its energy. In every case it is possible to trace the original source of energy back to the sun.

The Magneto.—If the magnetic field in the generator is produced by a permanent magnet, instead of by an electromagnet, the machine is called a *magneto*.

The Transformer.—The *transformer* is a device for increasing or decreasing the voltage, or pressure, of an alternating electric current. It consists of a core of layers of soft iron around which are wound two separate coils of insulated wire. One coil has more turns than the other. A current passing through the coil of fewer turns magnetizes the soft iron core and the magnetized core induces a current of higher pressure in the coil of many turns. This increase in electrical pressure is called a *step-up* in voltage. A current passing through the coil of many turns induces a current of lower voltage in the coil of few turns. This is known as a *step-down* in voltage.



A Simple Electric Transformer
It takes a current of one strength and changes it to a current of greater or less strength.

The transformer makes it possible to *step-up* the voltage, or pressure, of the current from a dynamo to so high a point that it easily overcomes the resistance offered by many miles of wire. Thus electricity can be sent long distances to points of use. At these points transformers step down the current to a pressure or voltage safe to use in our houses.

The Big Creek Power Co., in California, is said to transmit electricity of 160,000 voltage to Los Angeles, over 250 miles distant. The power plants at Niagara Falls transmit electricity of high voltage to many cities and villages within a radius of over 150 miles. By means of transformers at the receiving end, it is then stepped down and made available for use in running factories, in lighting cities, and in other ways.

The Electric Motor.—The electric motor is a machine constructed somewhat like a dynamo. It is used to make something move when it receives energy in the form of an electric current. While the dynamo changes the energy of motion into electrical

energy, the motor does the opposite thing; it changes electrical energy, supplied by the dynamo, into the energy of motion. It is another illustration of the transformation of energy. Electric motors are used to drive elevators, trolley cars, washing machines, pumps, and many other types of machines.

SUMMARY

Man in recent times has made electricity available for many practical purposes.

Electricity and magnetism are not the same but are closely related.

An electromagnet is a piece of soft iron encircled by a coil of insulated wire.

Among the common applications of electricity are the doorbell, the telegraph, and the telephone.

A magnet induces a current of electricity when moved within a coil of insulated wire. Such a current is called an induced current.

An induced current may also be produced by moving a coil of wire in the magnetic field of a magnet.

The dynamo is a machine for changing mechanical energy into electrical energy.

The transformer is a device for increasing or decreasing the electrical pressure of a circuit.

The electric motor is a machine for converting electrical energy into mechanical energy. It is used for many industrial and domestic purposes.

Fact and Thought Questions

1. In what practical ways have you used electricity?
2. Upon what does the strength of an electromagnet depend?
3. Describe the experimental work of Oersted. Why was it important?
4. What important discovery was made by Henry and Faraday?
5. Complete these statements orally:
   (a) The important parts of a telegraph circuit are ——.
   (b) An induced current is ——.
6. Define a relay and explain its function.

7. Compare the functions of a dynamo and an electric motor.
8. Name several practical household uses of electric motors.
9. Why will a thin wire become hotter than a thick wire under a heavy electric current?
10. Why do men handling electric wires often use rubber gloves?
11. Is it true or false that the speed of an electric motor increases with the increase of current? Why?
12. Name some advantages of transforming water power into electricity.
13. Why are house electric wires insulated and trolley wires not insulated?
14. Suggest how you think a physician might use an electromagnet to remove small pieces of metal that had become imbedded in the flesh.
15. Suggest advantages of an electromagnet over an ordinary hook and chain for handling scrap iron with a crane.
16. State the principle of the transformer. Describe a simple transformer. Name two uses of a transformer.
17. Describe the structure of a telephone transmitter.
18. Trace the various steps in transmitting a message from speaker to hearer over a telephone.
19. Name several ways in which the telephone has affected our modern life.
20. Why are the insulated wires of a house lighting system usually carried in metal tubing?

Projects

1. Make a labeled drawing of a simple electromagnet. Then construct the magnet.
2. Make a labeled drawing of a simple electric bell. Connect up a bell and study its workings.
3. Using the electromagnet already constructed, make a model of a simple electric crane. Demonstrate the lifting power of the electromagnet with nails and small bits of iron.

Outdoor Observation

1. Pay a visit to an electric light plant. Then observe the outdoor distribution system of the current. Notice the forms of insulators in use and the places where they are used. Notice how connections are made between street wires and the house meter.
2. Observe how electricity is distributed from power house to electric cars. Note the character of the rail connections. Notice the method of supporting the electric wires. Observe how the motorman controls his motor.

3. Visit a switch board or telephone exchange and learn how connections are made between telephones. Observe outside wiring and notice how telephone wires are run from the street wires into a house.

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CHAPTER XVII

APPLICATIONS OF ELECTRICITY

Electricity is one of the greatest servants of mankind. It may be sent far and wide, and is always ready to start work the instant we turn a switch or push a button. It has so utterly changed living conditions that conveniences now are available that were not even dreamed of a half-century ago.

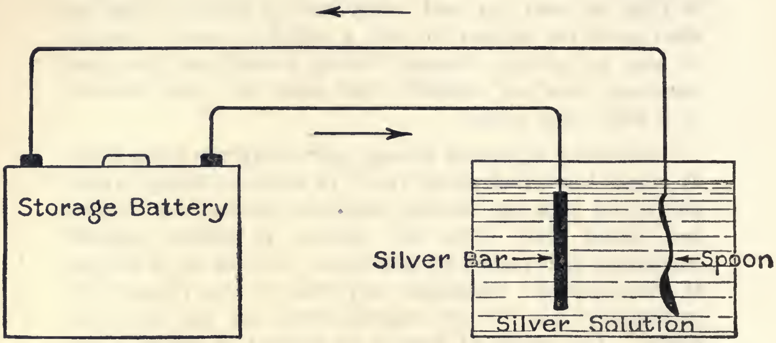
Electricity lights our homes, and sometimes heats them. It cooks food, and preserves it in electric refrigerators. Electricity runs our sewing machines, washes our clothes, and cleans dust from our rooms. It makes possible magazines and papers at low rates. It aids us in illness. It transmits our messages, and adds to our pleasure by gathering from the air entertainment for our free moments. The study of how it is applied is bound to be fascinating.

We have spoken of magnetic effects of electricity. There are also chemical and heating effects of great importance and interest. Among the processes depending on the chemical effects are *electrolysis, electroplating* and *electrotyping.*

Electrolysis.—Electrolysis is the process of breaking up a compound into its elements by passing an electric current through it. All compounds capable of conducting electricity when dissolved in water may be more or less broken up in this way. Water itself may be broken up into its elements, oxygen and hydrogen, by electricity.

Electroplating.—We often hear certain metal articles spoken of as plated ware. This means that some cheaper or stronger metal has been coated with another metal to render it more attractive, or to preserve it from injury by contact with the air. For example, iron spoons may be covered with a silver coating. This is done by passing a current of electricity through a solution of a silver compound. The spoons and a bar of silver are suspended in the solution by wires, the spoons from a rod connected with the negative terminal of the source of the

current, and the silver bar from a rod connected with the positive terminal. As the current passes through the solution, silver is deposited on the spoons. This silver is taken from the solution, where it is replaced by silver dissolved from the silver bar. When the spoons have received the proper thickness of coating, they are



Electroplating a Spoon

By means of an electric current, silver is taken from the solution and deposited on the spoon. The strength of the solution is sustained by silver drawn from the bar.

taken out and then rubbed with a smooth iron, called a burnisher, to give them luster. Plating with gold or other metals is done in a similar way.

Electrotyping.—Electrotyping is the process of making plates from type for use in printing. The majority of books are now printed from plates. First a mold of a full page of type is made of wax or papier maché. This mold is coated with a thin layer of graphite, a good conductor of electricity. This is necessary because wax and papier maché are poor conductors. Then the mold is connected with the negative pole of a battery and immersed in a copper sulphate solution. At the same time a thick plate of copper is connected with the positive pole of the battery and immersed in the solution.

The current forms a deposit of copper about the thickness of an egg shell all over the mold and makes a copper plate. Then the wax or papier maché is removed. To bear the impact of the printing press without breaking, this copper plate is

made strong and rigid by adding a layer of type metal to its under side.

Electrotyping has greatly reduced the expense, time, and labor involved in printing books, magazines and newspapers. It allows many plates to be made quickly and easily from a single page of type. These plates may be used over and over again and, being solid, are much preferable to pages set with individual type letters which might fall out of place. The great high-speed rotary newspresses could not operate without electrotype plates. To this process, then, we owe the many inexpensive books, magazines and newspapers which we enjoy today.

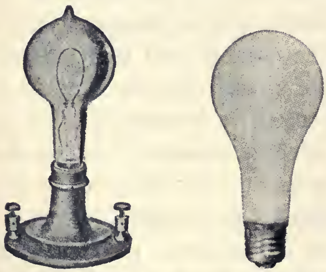
Electric Heating.—The fact that heat is produced in any material through which electricity flows, and is more or less intense according to the strength of the current and the resistance it meets, has led to the invention of many electric heating devices. Some of these are very convenient in household work and are widely used. Electric heaters, electric toasters, electric flatirons, electric grills, electric waffle irons and the like are found in many homes. In all of these devices the essential thing is a coil or coils of wire which offer such resistance to the current passing through that much heat is given off. Some metals have much more resistance to a current than others. In household devices wire made of nichrome is generally used, since it has a high degree of resistance and hence becomes very hot.

Electric Lighting.—Electric lighting, as well as electric heating, depends on the principle of the transformation of energy. When a substance is heated by electricity to a sufficiently high degree of temperature it glows because a part of the heat energy has been transformed into light energy. Taking advantage of this fact, man has invented several devices to produce artificial light. Among these are the *arc* light and the *incandescent* light.

The Arc Light.—The arc light is made by placing two pieces of hard carbon with their ends almost meeting and connecting them in an electric circuit. The current is forced to jump the gap between the ends of these carbons. Fine particles of carbon pass across from one to the other, forming an arc over which

the current passes. This arc becomes very hot. It produces one of the highest temperatures man has ever succeeded in obtaining. With this high temperature comes a very brilliant light. This method of lighting is both expensive and hard to control. In consequence, it is rapidly being replaced by the electric bulb.

The Incandescent Lamp.—The incandescent lamp, or electric bulb, was invented by Thomas Edison. It is a glass bulb from which the air has been extracted and in which is a fine filament or wire. When an electric current passes through this filament it becomes very hot on account of the resistance it offers and as a result the filament gives off a brilliant light.



General Electric Company. Brown Brothers.

INCANDESCENT LAMPS

Edison's First Successful Lamp. An Improved Lamp.

In the first incandescent light, air was extracted from the bulb, leaving a vacuum. This was done because otherwise the oxygen in the air would unite with the filament at the high temperature to which it must be heated. This would ruin the bulb. Later it was found that the quality of the bulb could be improved by filling it with some gas that would not unite with the filament. Nitrogen seemed to be the best gas, so the nitrogen bulb began to be used. Now, according to their uses, bulbs are filled with different gases, such as nitrogen, argon, neon or helium. Bulbs of special design are now used in heating, in scientific, and in radio apparatus. The tubes which form the letters of some electric signs are filled with neon. As an electric current passes through the tube, the gas glows.

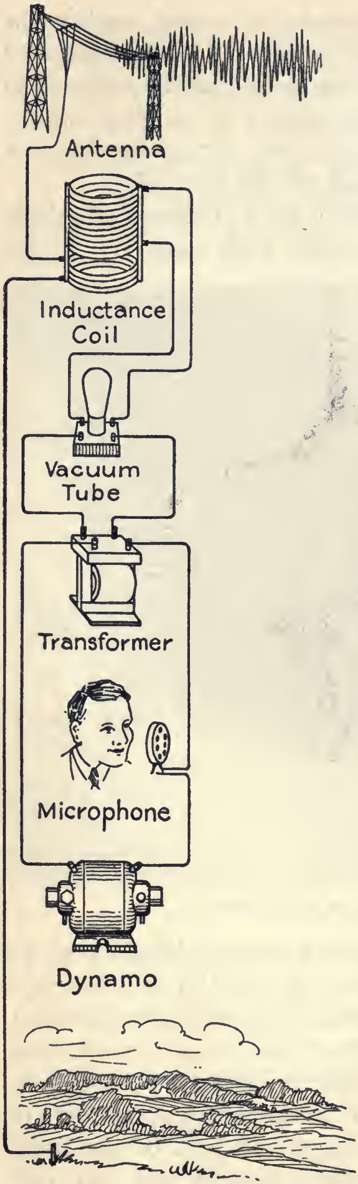
Fuses.—It sometimes happens that two electric wires in a house become crossed at a point where the insulation is worn away. Since electricity follows the path of least resistance, the current jumps from one wire to the other at this point rather than go around the circuit where the resistance is greater. This shortening of the circuit greatly increases the current and the wire becomes hotter until it may start a fire.

Fuses are installed in house circuits to protect against the dangers of crossed wires. A fuse consists of a short piece of wire with a comparatively low melting point, usually enclosed in a protecting cylinder or plug for convenience in inserting into the circuit. If the current becomes too great for safety the fuse melts and breaks the circuit, shutting off the electricity.

X-rays.—X-rays were discovered by a German physicist, named Röntgen, near the close of the 19th century. In the

X-RAY PHOTOGRAPH OF AN ELBOW

course of his experiments, while passing electric charges through a vacuum tube, he observed that a certain kind of radiation was given off which would pass through such opaque objects as wood, pasteboard and flesh. As the nature of these rays was unknown to him, he called them X-rays. These rays affect a photographic plate somewhat as sunlight does. When a photographic plate of sufficient sensitiveness is placed against any part of the body, such as the arm, and X-rays are passed through that part, they



An Early Broadcasting Set

will make a shadow picture upon the plate. The flesh will be faintly outlined but the bones will show a strong shadow. This picture is then developed like any photographic plate.

The value of the X-ray to man is very great. With its aid surgeons can determine the extent of any injury to bones and can locate foreign objects that become lodged in the body. Physicians also find the use of these rays valuable in the diagnosis of certain diseases involving growths on the lungs and other tissues of the body, for such growths cast a darker shadow than flesh.

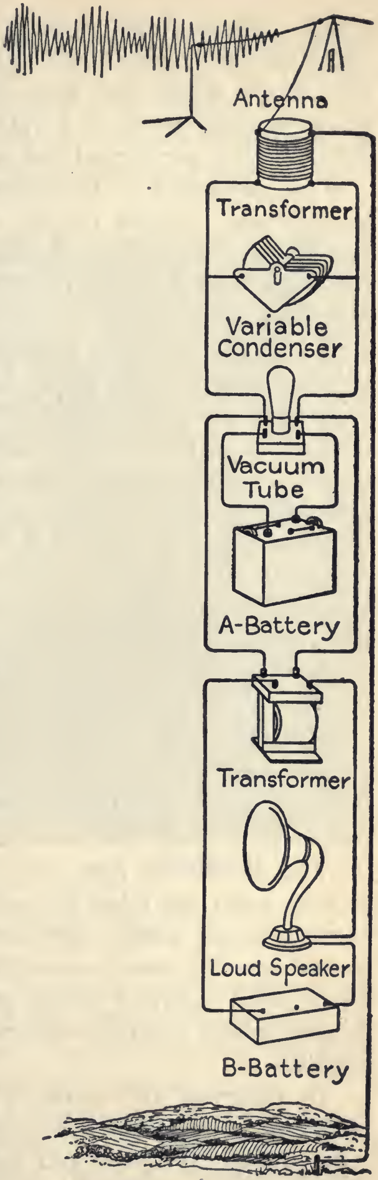
Radio.—Another form of radiant energy is illustrated in radio, or wireless communication. This is another example of the transformation of energy. Radio was made possible by a discovery made by Heinrich Hertz, a German scientist, in 1888. He discovered that certain electrical discharges through the air, known as sparks, are each made up of thousands of to-and-fro vibrations per second, which cause ether waves that radiate in all directions. In honor of the discoverer these waves are called Hertzian waves. Their to-and-fro vibrations are called oscillations. By observing the pendulum of a clock in action

you can readily get the idea of oscillation. Radio employs these Hertzian waves.

The Sending Station.—The sending or broadcasting station uses apparatus which forms Hertzian waves and projects them into space in all directions. In place of the spark, the more modern stations use the vacuum tube to generate the to-and-fro electric discharge which results in waves which go out from the antennae, or wires, high in the air. The vacuum tube gives a more uniform wave than the spark.

The principal parts of the sending set are the *dynamo, microphone, transformer, vacuum tube, inductance coil,* and *antenna.*

In broadcasting, the voice of the sender strikes the microphone, which is much like a delicate telephone transmitter, and causes a disk to vibrate. This vibration results in variations in resistance which cause the electric current passing through the transmitter to change the sound waves to electrical waves. The transformer increases the pressure of the current. Under this increased pressure, the current passes into the vacuum tube



AN EARLY RECEIVING SET

which produces rapid to-and-fro motions. The inductance coil regulates the length of the electrical waves before they reach the antenna where they pass into space. These electrical waves travel through the air at a rate of about 300,000,000 meters, or 186,000 miles, per second, the same speed as light.

One movement of the current in each direction through the vacuum tube is called a cycle. 1000 cycles is one kilocycle. The broadcasting stations in the United States vary in the number of cycles per second from 500,000 to 1,500,000, or from 500 to 1500 kilocycles.

Each cycle sends off one wave. The distance a wave travels per second divided by the number of cycles a station sends per second gives the wave length. For example, WEAF at New York may announce that it is operating under a frequency of 660 kilocycles, which is 660,000 cycles. 300,000,000 divided by 660,000 gives 454.54, the length of a wave in meters. The lengths of waves sent out by stations in the United States vary from 550 meters to 200 meters. However, new stations, known as short wave stations, are now appearing. Some of these send out waves less than a meter in length. These short waves have better carrying quality and do not require so much power.

The room in which the broadcasting is done is called the *studio.* It must be carefully constructed since any vibration or reflection of sound will affect the quality of the broadcasting. The early studios were hung with draperies to prevent echo. The more modern ones have walls made of sound-deadening material.

The Receiving Set.—A receiving set is necessary in order to take from the ether the messages of sending sets and turn them back into sound. The essential parts of a receiving set are the *antenna,* the *transformers,* the *variable condenser,* the *vacuum tubes,* and a source of electric current. The house lighting circuit is used where possible; otherwise batteries furnish the electric supply.

In receiving, the waves in the ether from the sending set strike the antenna and set up similar electric waves in its wires. The variable condenser and its transformer may be adjusted so that they let through only waves of a certain length, allowing but

one sending station at a time to be heard. These rapid electric waves now enter the vacuum tube. The antenna, the variable condenser, a transformer, and one part of the vacuum tube form a circuit. The current is supplied to this circuit from the house lighting current, after it has been stepped down by a transformer.

Keystone View Company.

A BROADCASTING STUDIO

Notice the singers standing by the microphones in the foreground. The walls are so constructed that they cause no echoes.

The purpose of this circuit is to return the waves as nearly as possible to the wave length which they had when they left the microphone in the sending station. The diaphragm in the loud speaker then translates these waves back to sound.

Tuning.—In order to receive messages, the apparatus at the receiving station must be so adjusted that it receives waves of the same length as those broadcast from the sending station desired. The effort to make the stations work in harmony is

called *tuning*. It will help you to understand this process if you consider the action of two pianos near each other. When they are tuned to the same pitch, a note struck on one piano will produce the same tone on the corresponding wire of the other. They are in tune and therefore vibrate, or oscillate, in sympathy. In a similar way, the apparatus of a receiving radio station must be in tune with the apparatus of the sending station; otherwise communication will not be effective.

Everyday Radio.—The radio sets just described are very simple ones. The big broadcasting and receiving sets have many complicated parts. These consist mainly of little refinements which serve to clarify tone, magnify volume, eliminate interference, and perform other helpful services. The parts named are those essential for radio sending and receiving.

Radio is playing an increasingly greater part in the lives of millions of citizens. Every day, scores of stations broadcast concerts, lectures, stock reports, weather forecasts, and news to any who care to tune in. Football games and World Series baseball games, once enjoyed by relatively few, are now broadcast play-by-play throughout the entire country.

The latest development in radio is known as television. It consists in sending the sound as in regular broadcasting and also projecting a moving picture on a screen attached to the receiving set. With this equipment one can hear whatever is being broadcast and see the broadcasters at the same time.

SUMMARY

Among the chemical effects due to electricity are electrolysis, electroplating and electrotyping.

Electrolysis is the process of breaking up a compound into its elements by passing an electric current through it.

Electroplating is coating a metal with another metal.

Electrotyping is the making of printing plates from type.

Electric heating is producing heat by means of electricity.

Electric lighting is producing artificial light by electricity.

Fuses are pieces of metal which melt at a moderate temperature, and are used to safeguard an electric circuit.

Another application of electricity is the X-ray, used largely in the practice of medicine and of surgery.

Radio, or wireless communication, is one of the most wonderful applications of electricity.

Fact and Thought Questions

1. What is meant by the chemical effects of electricity?
2. Describe the electrolysis of water.
3. Describe the method of electroplating.
4. Name several household utensils and furnishings that may be electroplated.
5. Name several common electric heating and cooking devices.
6. Explain the principle of electricity on which any electric heating device depends.
7. Name some advantages of electric heating devices in the home.
8. Describe the incandescent light.
9. How may one waste electric current?
10. What is a fuse? Explain its value.
11. What is the X-ray? Give practical illustrations of its use.
12. Name ways in which electricity is used for signaling.
13. What is radio communication? Name the essential parts of a radio receiving set.
14. Compare the use and value of phonographs and radios.

Projects

1. Bring a fuse to school, show its structure and explain its use.
2. Make a labeled sketch of the main parts of a radio receiving set.
3. Find out what you can about electric signals for street traffic or railroads. Explain the working of a simple system.

Outdoor Observation

1. Observe the electric lighting of streets, signs, and show windows in your neighborhood. Observe the arrangement of lights and the means taken to cast the light where it is most effective or of most service.
2. Observe the different forms of radio aerials in your neighborhood. Observe how they are mounted, and how wire connections are made.
3. Summarize all the uses of electricity you observe in your neighborhood.

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GENERAL THOUGHT QUESTIONS FOR DISCUSSION AND REVIEW

GROUP III

1. Does the sun give us any heat when there are thick clouds overhead? Why?
2. Why is it hard to walk against the wind?
3. An explosion occurs within your sight. Do you see the flash before or after you hear the explosion?
4. If an earthquake occurred in California at 3 P. M., could news of it appear in the 5 P. M. edition of an eastern paper?
5. Why do the wires strung on telephone poles hum?
6. Suggest ways in which a chimney adds to health.
7. Why are there so many lightning strokes without apparent damage?
8. Why are fuses installed in electric lighting circuits?
9. Why do all the lights of a one-string Christmas tree set go out if one bulb burns out?
10. Suggest a reason for keeping bars of steel on the ends of permanent magnets.
11. Why does wind sometimes prevent sound, but never light, from reaching us?
12. Why does gasoline feel colder on the hand than water?
13. Why do animals prick up their ears at unexpected sounds?
14. Why do we hear an echo distinctly in one spot and perhaps not at all a few steps away?
15. Suggest how the noise of an explosion is produced.
16. Suggest how perspiration reduces one's temperature.
17. Why are safes that have been through hot fires generally permitted to cool before being opened?
18. Why is ice in old style icehouses packed in sawdust?
19. Why do extremely sharp sounds injure the ears?
20. Is there any advantage in opening the mouth if you are expecting to hear a sharp explosion? Why?
21. Why does not a pane of glass cast a shadow?
22. Is it true or false that dark clothing is warmer than light clothing of the same material? Why?
23. Would a magnet help us to find the proverbial "needle in the haystack"?
24. Why does a clock with a metal pendulum have to be regulated winter and summer?
25. Why does an image seen through a window sometimes appear distorted?
26. Why are tall steel buildings seldom damaged by lightning?

27. When the insulation wears off a lamp cord, why does a fuse often blow out?
28. Why are thick steel rods used as lightning rods rather than thin wire?
29. Would a heavy car or a light car, having the same braking surface, be likely to wear out its brakes first? Why?
30. Why do fogs often fill hollows and not the high points?
31. If wind sets in from the northeast, from what direction will an approaching storm arrive?
32. Discuss in a paragraph a drinking water supply under the following heads: (a) its source and the reasons for the selection of this source, (b) how the water pressure is secured and how the water is brought to a town or city, (c) sanitary precautions for keeping the water pure.
33. Why do some outfielders in baseball start running when they hear the bat strike the ball though they do not yet know just where they are to go?
34. Will a white post or a black post cast a darker shadow?
35. A part of the current that comes to a trolley car from the wires passes through the rails. Why do we not get a shock if we touch the rails?
36. What property of hydrogen makes it good for use in airships and what property makes it dangerous?
37. Why does a toy motor make more noise when running on the bare floor than when running on carpet?
38. Why is it advisable to have lightning rods grounded in moist earth rather than in dry earth?
39. Name some advantages of electric power over steam power for running (a) factories, (b) street car lines.
40. Why do rubber suction discs stick to a wall?
41. Why will hot liquid cool quicker in a tin cup than in a wooden bowl?
42. Is it true or false that rainwater drawn from the ocean by the sun is different from rainwater drawn from a lake?
43. Why is it hotter on a white sandy beach than on dark earth?
44. Why does a dentist use a concave mirror in his work?
45. Why is it advisable not to fill an automobile radiator to the top with an anti-freezing mixture?
46. Why does a lake change color under different weather conditions?
47. Is food chilled more quickly if placed at the top than if placed at the bottom of a refrigerator?
48. How does an electric fan cool us?
49. Suggest ways in which the free-moving property of air is an aid to us.

CHAPTER XVIII

MACHINES

Early man once worked with his hands alone, unaided by any tool. When, however, he found that an object, perhaps a boulder, too heavy to move by hand, could be pried from its bed by means of a long, tough stick, he made a discovery that later gave us scissors and wheelbarrows, claw hammers and knives and many common tools and devices.

He discovered, also, that objects too heavy to lift to a new level could easily be rolled to that level up a smooth incline. These discoveries marked the beginning of machinery.

Today, in home and office, we use hundreds of machines and labor-saving devices. We depend on them every hour of the day. Machines make possible our comforts, our travels, and in many ways provide pleasures and protect health.

By the use of machines we harness, for our service, the wind, water, steam and electricity. By a pull on a lever, or a turn of a wheel, a single man controls and directs a power equal to that of hundreds of horses.

In such complicated modern machinery as great printing machines, weaving machines, and express locomotives, we find merely the early machines perfected and applied in new ways.

A *machine* is a device for transforming and applying energy and for making work easier or less burdensome. In early times man did nearly all work with his hands. Gradually he learned how to make and use machines or tools to provide for his three greatest needs, food, clothing and shelter.

The lot of mankind has greatly improved through the ages with the development of machines in the many different industries. The march of civilization may be traced by a study of the

gradual substitution of machine for manual labor. It is largely by means of machines that the transformation of energy is effected.

There are a few words and phrases whose meanings we should know in order to understand the principles involved in machines. Important among these are *energy, work, foot pound, force, effort, power, friction* and *mechanical advantage.*

Energy is the capacity to do work.

Work is the overcoming of resistance. It is the result of motion caused by force.

The foot pound is the unit of work. It represents the work done in lifting a pound avoirdupois a distance of one foot.

Force is the use of energy in the effort to do work. It is usually measured in pounds. A pound of force is equal to the pull of gravity on a one pound weight.

Effort is force applied to move a weight or overcome resistance.

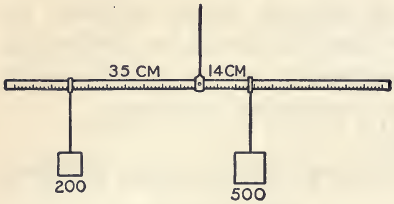
Power is the rate of doing work. It is measured in terms of horse power. One horse power represents the ability to do 550 foot pounds of work per second, or 33,000 foot pounds per minute.

Friction is the resistance which a body meets with in rubbing against another body. It hinders the motion of machines and causes loss of work, the amount of loss being dependent on the conditions of the surfaces that come in contact.

The mechanical advantage of a machine is its efficiency as measured by the force it exerts divided by the force applied to it to make it work. If a machine lifts a 4 pound weight when 1 pound of force is applied to it, its mechanical advantage is $4 \div 1$, or 4.

You are more or less familiar with machines. You have seen sewing machines, mowing machines, washing machines, automobiles, airplanes, bicycles, steam engines, dynamos, and many other complex machines, as well as such simpler ones as nut crackers, tongs, and hammers. There are six simple machines—the *lever,* the *inclined plane,* the *wedge,* the *screw,* the *pulley,* and the *wheel and axle.* Since the pulley and the wheel and axle are only variations of the lever, the study of the lever will help us to understand their action. Since the wedge and the screw are only variations of the inclined plane, the study of the plane will help us to understand the action of the wedge and the screw. All complex machines are merely two or more simple machines combined in such a way that they work together.

The Lever.—The lever is a rigid bar arranged to turn on a fixed support, or axis, called the *fulcrum* (F). By its use, a limited force, or *effort,* may overcome a large *resistance* or *weight.* The distance on the bar from the fulcrum to the point of support of the weight is called the *weight arm,* or *resistance arm* of the lever. The distance from the fulcrum to the point where the effort is applied is known as the *force arm,* or *effort arm* of the lever.



A Balanced Lever
Why does the small weight balance the large one?

The force used in a lever or other machine is called the *effort* (E), whether it is the pressure of water, the pull of gravity, or any other force. The resistance to be overcome is the *weight* (W).

Experiment to Illustrate the Lever.—First balance a meter stick by supporting it at its middle point. This support is the fulcrum. With a cord hang a 500-gram weight on the meter stick from a point 14 centimeters from the fulcrum. This is the weight, or resistance. Then find a point on the other side of the fulcrum at which a 200-gram weight, the effort, will just balance the 500-gram weight. This point will be 35 centimeters from the fulcrum on the other side. A meter stick so arranged is a lever.

Notice that 500, the weight, multiplied by 14, the distance from the fulcrum, exactly equals 200, the effort, multiplied by 35, its distance from the fulcrum. Both products are 7,000. This illustrates the general truth that when two different weights are just balanced, the product of one weight multiplied by its distance from the fulcrum is always equal to the product of the other weight multiplied by its distance from the fulcrum. In other words, the weight multiplied by the weight arm equals the effort multiplied by the effort arm. This is known as the *principle of moments* and is applied in common forms of scales.

Classes of Levers.—Levers are divided into three groups, known as levers of the *first, second* and *third classes.* The class to which a lever belongs is determined by the relative location of

the effort, the fulcrum, and the weight. In the first class the fulcrum is between the weight and the effort. Examples of this class are common shears, pliers, ordinary steelyards or scales, and seesaws. In the shears the fulcrum is at the hinge, the effort at the handle, and the weight is at the point where the cutting is done. Can you locate the fulcrum, the weight, and the effort in the other objects referred to?

In the second class, the weight is between the fulcrum and the effort. Examples of this class are the oar of a boat, the wheelbarrow, and the long-handled lemon squeezer. In the use of the oar, the arm of the rower is the effort, the boat is the weight and the water pressing against the blade of the oar is the fulcrum. Locate the fulcrum, the weight, and the effort in the other objects named.

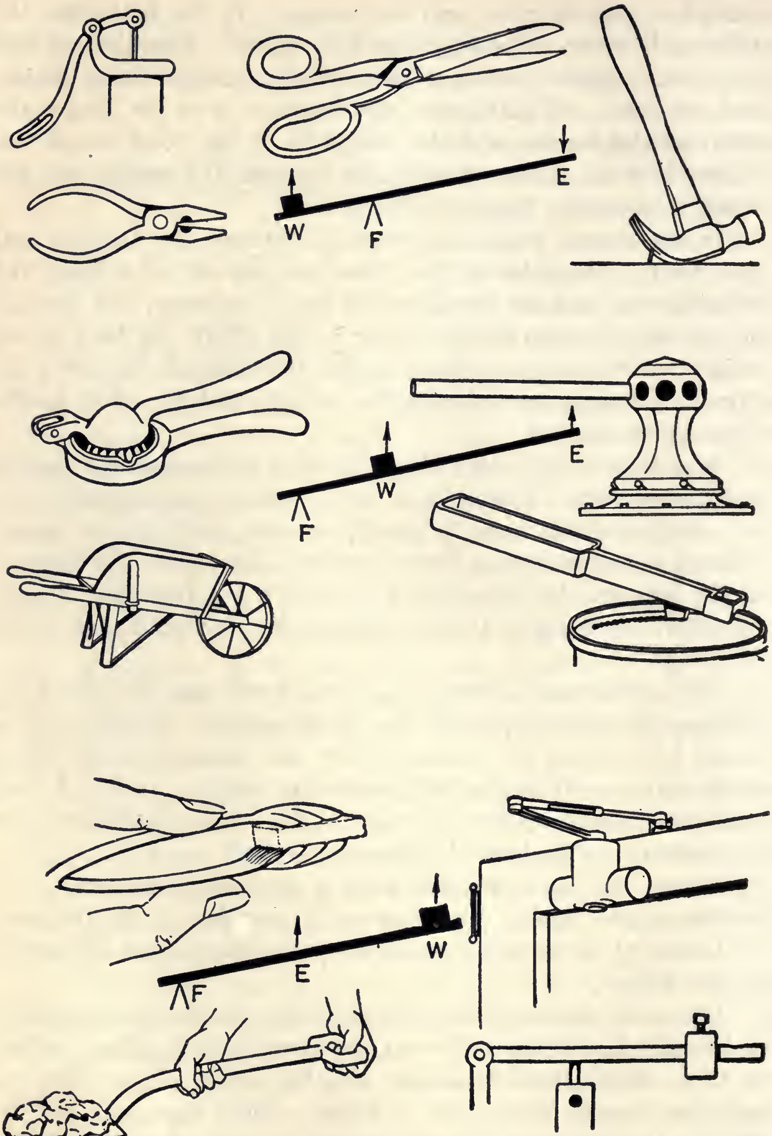
In a lever of the third class the effort is between the weight and the fulcrum. Examples of this class are the leg and claws of a bird, the treadle on a sewing machine, and the fire tongs. When a bird rests upon a perch, its body is the weight, the muscles of the legs are the force, and the perch is the fulcrum. Locate the effort, the weight, and the fulcrum in the treadle and in the fire tongs.

The mechanical advantage of any lever may be found by dividing the weight lifted by the effort applied. It may also be found by dividing the distance from the fulcrum to the effort by the distance from the fulcrum to the weight. If it is 5 feet from the fulcrum to the effort and 1 foot from the fulcrum to the weight, the mechanical advantage is $5 \div 1$, or 5.

Levers of the first class have a mechanical advantage of greater or less than 1, depending on the location of the fulcrum.

Levers of the second class always have a mechanical advantage greater than 1.

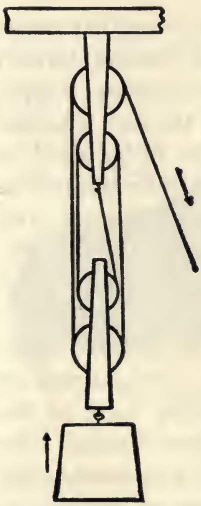
Levers of the third class always have a mechanical advantage of less than 1. While they exert less force than the effort applied to them, they offer advantages in other ways. Your forearm and the muscles that move it form a third class lever. The elbow is the fulcrum. The point on the forearm where the muscle of the upper arm is attached is the point where the effort is



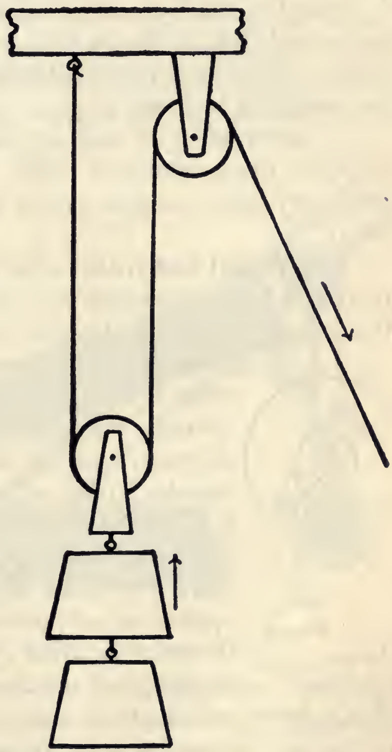
APPLICATIONS OF THE THREE CLASSES OF LEVERS
Name the fulcrum, the effort and the weight, in each case.

applied. The forearm is the weight. A short contraction of the muscle of the upper arm causes the forearm to move quickly through a considerable distance, though with far less force than the effort applied. Speed and distance of movement make up for the loss in mechanical advantage.

The Pulley.—The principle of the lever is employed in the pulley. The *pulley,* like the lever, is used for applying force to do work, such as lifting some heavy object from a lower to a higher level. A pulley, in its simplest form, consists of a grooved wheel so arranged as to turn within a frame or block by means of a cord or rope passing over the wheel.



BLOCK AND TACKLE
A little force will lift a heavy weight. Why?



A FIXED AND A MOVABLE PULLEY
Which pulley gives mechanical advantage?

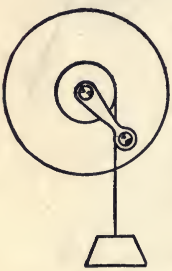
The single *fixed* pulley is fastened to a standard of some kind, and never gives a mechanical advantage of more than 1.

Its main use is in changing the direction of the force applied, but the amount of force needed is no less than without a pulley. For example, by means of a fixed pulley, a weight may be lifted vertically by a pull in any convenient direction.

The single *movable* pulley is fastened to the weight and moves with it. One end of the rope is fastened to a support. This corresponds to the fulcrum of a lever. The rope then passes through the pulley, which corresponds to the weight. The effort is applied to the free end of the rope. Being a modified lever of the second class, it always gives a mechanical advantage of greater than 1. That is, it requires less effort, measured in pounds, than the weight to be lifted.

A combination of one or more movable pulleys with one or more fixed pulleys is called a *block and tackle.* With its help, very heavy weights can be moved with comparatively small effort.

The Wheel and Axle.—The wheel and axle is another variation of the lever. It consists of a cylinder, the axle, to one end of which is fastened a wheel or a handle. Around the axle is wound a rope, one end usually being fastened to the axle and the other being connected to the weight to be lifted or moved. Turning the wheel or the handle rotates the cylinder, causing the rope to wind up on it and thereby lifting or moving the weight. The windlass, used to hoist water from wells, is a familiar form of wheel and axle.



WHEEL AND AXLE

Why is this a lever?

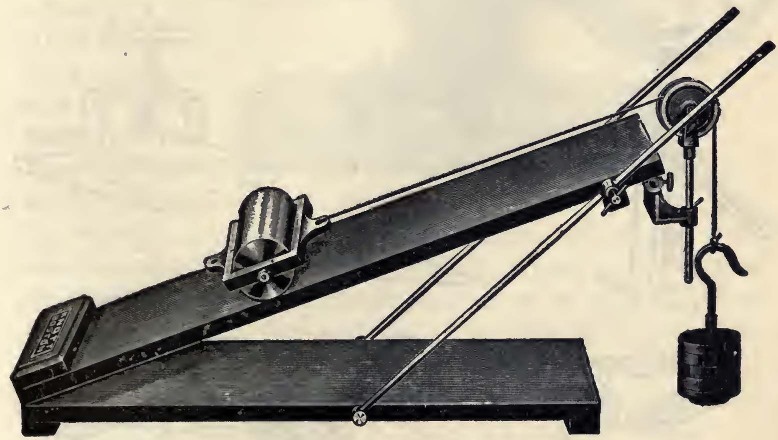
The steering apparatus of an automobile is an application of the wheel and axle. A slight pull on the steering wheel exerts great turning force on the steering rod, which corresponds to the axle. The steering rod, instead of winding a rope, exerts its force on rods connected with the front wheels.

The Inclined Plane.—The inclined plane is a flat surface set at an oblique angle to the plane of the horizon. The effort required to move any weight upward along such a surface is less than that required to move it vertically. If a boy attempts to lift a barrel of apples into a wagon and finds his strength is not

sufficient to do it, he may accomplish his purpose with comparative ease by rolling the barrel up a long, inclined plank and by exerting his force in a direction parallel to the incline.

The boy accomplishes the same work whether he lifts the barrel directly into the wagon, or rolls it up the incline. He moves it farther by rolling it up the incline, but with less effort.

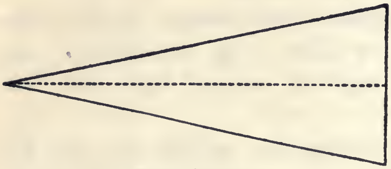
It is evident that the more gradual the incline, the less the effort necessary to accomplish the work. The mechanical advantage gained is equal to the length of the inclined plane divided by its height. If the length is four times the height, then a force of one pound will balance a weight of four pounds on the inclined plane.



THE INCLINED PLANE
A small weight holds the heavy roller in its place. Why?

The stairways in our houses are inclined planes, the steps merely enabling us to obtain a firm foothold. Highways and railroads are constructed so that the grades are as gradual as possible. Much more effort is needed to drive an automobile or an engine up a steep hill than up one of the same height where the rise is gradual. Naturally the distance covered is greater. Power is gained at the expense of time in the use of the inclined plane.

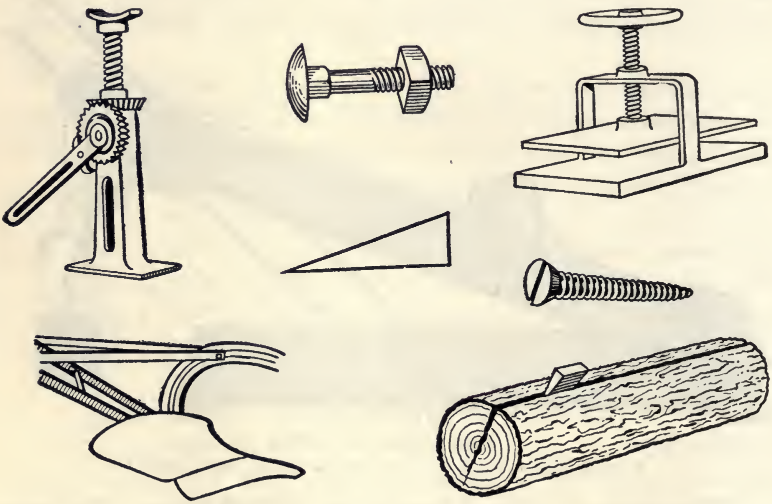
The Wedge.—The wedge is a combination of two inclined planes. The longer the wedge the greater its mechanical advantage.



The Wedge
A double inclined plane.

The wedge is employed, by means of blows on the thick end, to split rocks, timber, and other objects difficult to separate into parts by other methods. Axes, hatchets, knives, and other cutting instruments sloped on both sides of the cutting edge are constructed on the principle of the wedge.

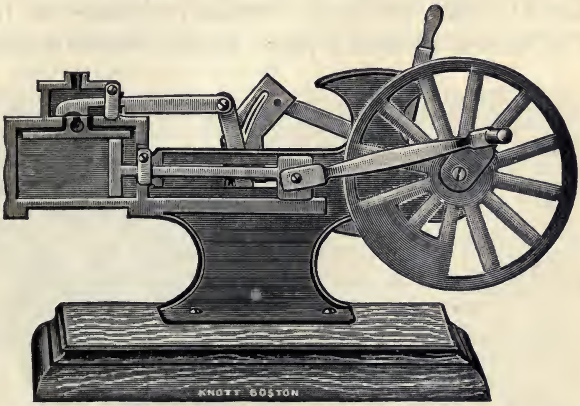
The Screw.—The screw is an inclined plane wound round a cylinder, thus making a circular inclined plane called the thread



Applications of the Inclined Plane
How is the inclined plane applied in each case? What other elementary machines do you see?

of the screw. The screw is used in combination with the lever in moving large or heavy bodies through short distances. It is also employed in presses of all kinds where considerable force is needed, as in bookbinders' presses. Another illustration of the screw is the automobile jack.

The Steam Engine.—The *steam engine* is an illustration of a complex machine built up by combinations of simple machines. Like all heat engines it transforms heat energy into mechanical energy. The modern steam engine has developed from one invented in the latter part of the 18th century by James Watt. It depends for its efficiency on the energy released by molecules of water when heated. Heat causes the molecules to become very active so that some of the water changes to steam, expands, and exerts great pressure. This steam when conducted into the cylinder of a steam engine comes into contact with a body called a piston, a cylindrical body which can move back and forth within the cylinder. By allowing the steam to enter the cylinder, first at one end and then at the other, its expansive force pressing against the ends of the piston causes it to move back and forth in the cylinder. The motion thus generated is communicated to a shaft with which the piston is connected, and the motion of the shaft is passed on to other parts of the machine.



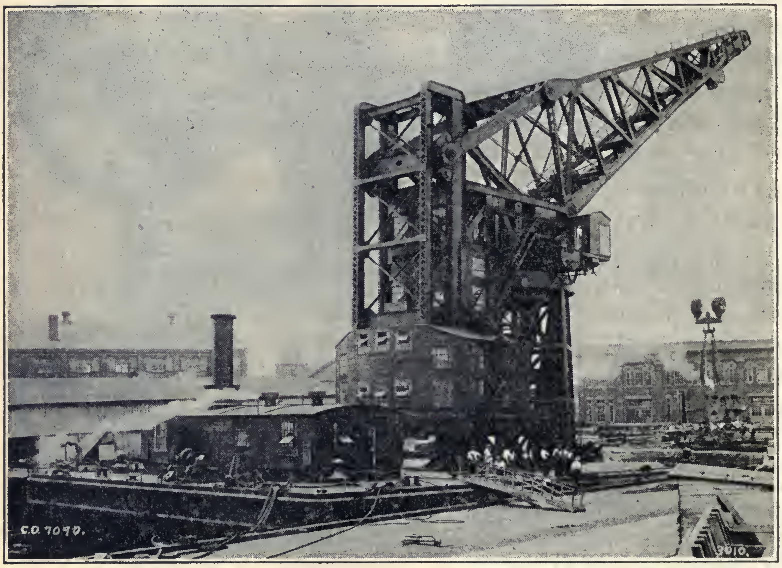
A Stationary Steam Engine

The stationary steam engine is extensively used in driving machinery in factories. It is largely responsible for modern manufacturing methods.

Friction.—Friction usually reduces the working efficiency of a machine. We know how difficult it is to run a lawnmower, or any household machine with movable parts, unless it is well oiled. The tiny roughnesses of the metal surfaces which rub each other prevent easy movement and cause waste of energy. Oiling, however, coats these surfaces with free-moving oil particles which

cover the roughnesses and prevent the metals from actually touching. Because rolling contact causes less friction than sliding contact, tiny metal balls or rollers, called roller bearings, are often used between moving metal surfaces of machines.

Under certain circumstances, friction is helpful, even necessary. As the locomotive engineer sands a slippery track, so we sprinkle ashes on an icy sidewalk, to make the friction greater. The friction between a pencil and our fingers enables us to hold it.



Brown Brothers.

A Giant Crane

A complex machine made up of many simple machines.

We would be unable to start or stop an automobile without friction between the tires and the road. Without friction we would be helpless.

Energy and Machines.—In all machines, the principle of the conservation of energy is illustrated. When energy is used in the work of a machine none of it is lost. Some of it may disappear in friction, which changes it to heat, but much of it always appears as work accomplished. Remember that energy

may be transformed but it cannot be created or destroyed. Energy never comes from anything that is not energy.

It is reported that the United States Patent Office receives many applications for patents on machines which will work continuously without the use of fuel or the acquirement of energy from any other source. Such machines are called perpetual motion machines. The principle of the conservation of energy shows that a perpetual motion machine is impossible because it requires the creation of energy out of nothing.

SUMMARY

A machine is a device for transforming and applying energy and for making work easy or less burdensome. Work means the overcoming of resistance.

The mechanical advantage of a machine is its efficiency as measured by the force it exerts divided by the force applied to it to make it work.

There are six simple machines, the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw.

The lever is a rigid rod arranged to turn on a fixed support called the fulcrum.

Levers are divided into three classes, according to the relative position of the fulcrum, the effort and the weight.

The pulley and the wheel and axle are modifications of the lever.

The inclined plane is a plane surface set at an oblique angle to the horizon.

The wedge and the screw are modifications of the inclined plane.

Friction usually reduces the working efficiency of a machine. In many of our ordinary activities, however, friction is helpful or necessary.

Fact and Thought Questions

1. What is a machine? Give examples.
2. Define: (a) work, (b) force, (c) energy, (d) power, (e) friction.
3. Name and describe the two basic forms of machinery.
4. What are the six simple machines?
5. Describe the lever and give examples of each class.

6. What sort of a machine is a crowbar? Can heavier work be done with a long-handled bar or with a short-handled bar?
7. Where would you place a heavy weight in a wheel-barrow in order to wheel it most easily?
8. Describe the inclined plane. Name several simple machines which make use of it.
9. Why should the surface of an inclined plane be smooth and hard?
10. Describe the wheel and axle and its use.
11. What is the advantage of rollers or casters under heavy objects?
12. How does your own body illustrate the principles of the lever?
13. Name several machines used in or about your home. State the simple machines involved in each. How does each save human labor?
14. Look at an engine or study a diagram of one. What simple machines do you find used in it?
15. Name several machines which have contributed much to human progress.
16. Is it true or false that a machine makes energy?
17. Suggest several activities in which you have to overcome friction. Suggest several ways in which you make use of friction.

Projects

1. Construct a movable pulley. Experiment with it, using known weights and a spring scale. Record your findings.
2. Locate a lever of each class in your body and explain its use.
3. Make labeled diagrams to show how the principle of the lever is used in standard beam scales.
4. Secure a spring scale and a flat bottomed box. Fill the box in turn with different substances, and determine the pull necessary in each case to hold it stationary on a wooden inclined plane and to draw it up the plane. Repeat the experiments after coating the plane and the base of the box with other substances, such as cloth or sandpaper. Record your findings and conclusions.

Outdoor Observation

1. Study some large machine at work—such as a steam shovel or a harvesting machine. Make simple labeled sketches to show what elementary machines are used in it.
2. List six tools or machines seen on your way to school. Observe what simple machine forms are made use of in each.

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CHAPTER XIX

TRANSPORTATION ON LAND

Highways have always played a large part in world history. All great nations, ancient and modern, have built roads connecting important points so that they could carry on commerce, or move armies rapidly from place to place and keep control over their territory. The famous roads of the Romans, which endured for centuries, had much to do with Rome's world power. The great highways of the Aztecs in Mexico and of the Incas in Peru were necessary for their greatness. No cost in lives or labor was too much to pay for them.

Science in this last century has made possible the building of roads and bridges with far less man-power than of old, and has steadily improved means of transportation. We travel farther in a day than formerly in weeks, and with much more comfort and safety. Science has supplemented the old highways with railroads so that the faraway country now serves our cities, and all sections of a nation are bound closely together.

Early man dwelt in family groups. He found shelter in caves or under rude brush covers, and obtained food from his immediate surroundings. He had no more possessions than could easily be carried in his hands. If food failed, families simply moved to a more favorable territory. As possessions gradually grew, they were moved in packs carried on the back. Later, when the horse had been made to serve man, drags similar to those of the American Indians were used. The drag has been likened to a wheelbarrow with a horse in the place of the wheel and the handles dragging on the ground. Under such conditions man did not require roads. He found the easiest way across country, fording streams in shallow places.

As man learned to live in larger groups, however, and discovered the value of dividing labor so that some secured food, others made weapons, and others built shelters or made clothes,

and as his possessions continued to increase, it became more necessary to have new means of transportation. Human and animal pack trains helped considerably, but with the increasing need of carrying food and supplies better means were required. Carts were invented which could carry heavier loads. The first carts were simply rough platforms rolled on logs. These were followed by carts with solid wooden wheels, mere sections of tree trunks, such as are still used in many outlying parts of the world. The early carts were two-wheeled affairs. In fact, it took something like 5,000 years to develop anything like the modern wagon of four wheels, with spokes and metal tires taking the place of the solid wheels.

Roads.—Wheeled vehicles could not go anywhere and everywhere, so some form of road became necessary, and also rude bridges by which to cross the larger streams. The first roads were simply stretches cleared of growing trees, often with the stumps left where the trees had been. They were rough and rutty and often impassable. By degrees man learned to cover the softer spots with brush and corduroy, logs laid side by side. Finally the greater of the ancient nations built their roads of great slabs of stone and some cement-like materials. Many of these roads endured for ages.

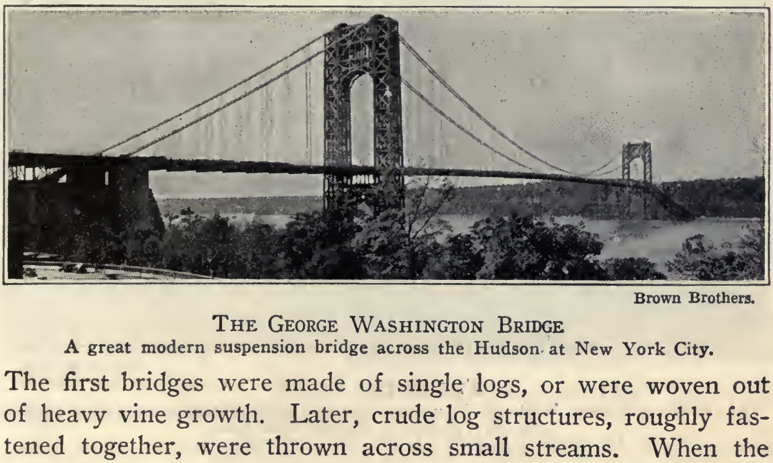
With the development of the automobile, durable roads and highways have become vitally necessary. Macadam roads were the first of the modern types. These are constructed of several inches of broken stone, overlaid with thin layers of fine stone and stone dust. The surface is curved to shed water and then rolled. To preserve the surfaces of these roads, they are oiled with compounds of tar or of asphalt, which is a natural tar-like, pitchy substance. Sometimes the fine stones in the top layers are thoroughly mixed with these compounds before being laid.

Brown Brothers.

A Modern Concrete Road

Other modern roads are built of concrete, asphalt or brick. The concrete, or cement, road is made of a mixture of broken stone and sand, bound together by a stone powder, called cement. When these materials are properly moistened and laid they *set* and form a solid rock-like pavement that will support very heavy loads. Asphalt roads are constructed by spreading layers of asphalt over a concrete base. This material is usually made firm and smooth by steam rollers. Modern brick pavements consist of bricks laid on edge on a sand cushion over a concrete base. Wood blocks are sometimes used in place of bricks because they deaden the noise of traffic.

Bridges.—In like manner, science has made possible great steps forward in bridging streams on the line of roads or trails.



Brown Brothers.

THE GEORGE WASHINGTON BRIDGE
A great modern suspension bridge across the Hudson at New York City.

The first bridges were made of single logs, or were woven out of heavy vine growth. Later, crude log structures, roughly fastened together, were thrown across small streams. When the science of mathematics showed how to compute the strains in beams, so that bridges could be built to stand the weights they were supposed to carry, it was not long before simple bridges of framed timbers were developed.

By degrees wood gave way to iron, capable of supporting heavier weights and covering greater spans. When iron gave way to steel, spans hundreds of feet in length could be built, or steel wire cables could be constructed to hold up the enormous weights of the modern *suspension* bridges. All these developments were

necessary to make it possible to use effectively the new means of transportation which were being invented.

Bridges built in the form of open frameworks of wood or metal are known as *truss* bridges. The beams and rods, or members, of these frameworks are so designed and arranged as to secure great strength with a comparatively small amount of material. Ordinary truss bridges rest on piers, or supports, with one end fixed and the other end on rollers or rockers, to allow for expansion or contraction with changes of temperature.

Cantilever bridges are framed structures built out from opposite piers, and so designed that each section is self-supporting.

Brown Brothers.

THE QUEBEC BRIDGE

The cantilever trusses, built out from each pier, are self-supporting. At their channel ends they support a regular truss span.

These sections may meet at the center, or may support a regular truss between their free ends. In this way, very wide spans between piers are constructed.

Travel by Wagon.—As communities grew and it became more and more necessary for food and supplies to be distributed among the settlements, stage and freight lines were established to serve the public. The early stage coaches, running with four or six horses or more, changed at frequent intervals, made fairly rapid time but could not carry many people. The early freight

lines, especially in our own country, consisted of heavy covered wagons drawn by many pairs of horses or yokes of oxen. They traveled very slowly.

The Locomotive.—With the invention of machinery for manufacturing, so that large factories began to take the place of the home industries, and with the growth of cities requiring heavy supplies of food, the problem of land transportation became more serious. Fortunately, a new means of travel was becoming available. In the latter part of the 18th century James Watt, an Englishman, invented a practical stationary steam engine to drive machinery. Attempts to apply the principles of the stationary engine to a locomotive which would run on rails promptly followed. In a comparatively short time railways began to develop in England as their value was appreciated. In this country the first practical railroad was not built until 1829. Forty years later the first railroad across the country was constructed. Thereafter, railroads grew rapidly, especially out from the larger cities. They opened up to settlement new areas of country and were responsible for the rapid development of farming districts and of industries. Today the country is covered with a network of rail lines.

THE FIRST TRAIN IN NEW YORK STATE

The early locomotives used wood as fuel. Later, coal and oil were substituted. For many years following the Civil War the size of the locomotive did not materially change. Between 1895 and the present, however, there has been rapid improvement and great increase in the size and power of locomotives, until today locomotives are made that will draw more than 100 heavily loaded freight cars.

The great power that locomotives exert is due to the great expansive force of steam. A given quantity of water, heated to steam, will occupy over 1,700 times its original space, if left free to expand. If confined in a small space it necessarily exerts tremendous pressure.

While the modern locomotive is a very complicated piece of machinery, the really vital parts are relatively few. There is the fire box, where coal or oil is burned; the tubular boiler, a mass of parallel tubes within a metal cylinder in which water is heated and turned to steam; the cylinders, in which the steam's energy is changed to motion, and the drive wheels, which use this energy of motion to move the train.

International Newsreel.

A Modern Steam Locomotive

The fire is made intensely hot by a draft caused by forcing used steam out through the smoke stack, thus creating a partial vacuum. This draws air through the fire. Steam is generated, stored in the steam chests, and admitted to the cylinders by sliding valves. The amount of steam admitted is controlled largely by a throttle in the engine cab.

Steam is admitted into each cylinder in front of the piston, a solid, cylindrical block capable of sliding back and forth in the cylinders. The expansion of the steam forces the piston sharply back within the cylinder. Then the inlet valve closes

and another opens admitting steam on the opposite side of the piston, driving it to its first position and forcing out the expanded steam through another valve that opens at the same time. This process causes the reciprocal, or back and forth, motion of the piston. The piston is connected with a shaft running through the end of the cylinder and joined with a connecting rod which is coupled with the drive wheels of the locomotive near their rims. The back and forth motion of the piston shaft is thus converted into circular motion, causing the drive wheels to turn and so move forward by reason of their friction with the rails.

The weights of the connecting rods destroy the balance of the drive wheels to which they are attached. This would tend to cause the wheels to pound the track. To restore this balance weights are built into each drive wheel near the rim. The heavier an object is, and the faster it is moving, the harder it is to stop it. This combined effect of weight and speed is called *momentum*. The weights built into the drive wheels add to the momentum of the locomotive, and tend to make less steam pressure necessary in drawing loads after a train is once started. The drive wheels on the two sides of the locomotive are so coupled that the connecting rods will not both be horizontal at the same time. Otherwise, it might be impossible to start the engine.

By means of a steel rod, or "link," which the engineer controls by a lever, it is possible so to shift the adjustments of the driving machinery of a locomotive that the motion of the connecting rods forces the drive wheels to revolve in the opposite direction and so sends the locomotive backward.

There must be sufficient friction between the rims of the drive wheels and the rails on which they run to make the wheels cling to the rails and cause forward motion, instead of slipping under a load. This is accomplished in part by the weight of the locomotive itself which makes its wheels press heavily upon the rails and so increase the friction grip upon them. It is also accomplished by using two or more drive wheels on each side. This not only increases the "gripping" power of the locomotive, but distributes its tremendous weight which, if centered at very few points of contact, might be too heavy for rails and roadbed.

High-speed locomotives frequently use two large drive wheels on each side. Heavy freight locomotives use three or four smaller ones, and tremendous compound locomotives may use as many as twelve drive wheels on each side, divided into two or more sets, each set having its own cylinder.

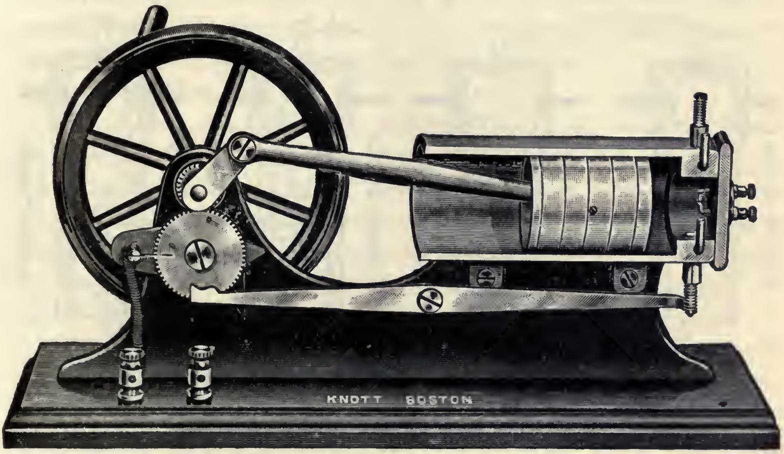
Great strain comes on a locomotive in starting a heavy train. Once it is started, momentum helps to keep it going. If it happens that tracks are oily or frosty, the drive wheels may simply spin when the engineer attempts to start the train. This trouble is usually overcome by sanding the rails, that is, by letting a small amount of sand flow through a tube from a sand box on the top of the locomotive to the track immediately in front of the wheels.

Owing to momentum, caused by their exceptionally heavy weight and speed, modern trains are exceedingly difficult to stop, once they are started. In the early days, with lighter trains, hand brakes were used. Today all trains are equipped with modern air brakes. The locomotive runs an air pump which compresses the air for the brakes, storing it in a reservoir from which it flows through an air hose to the car reservoirs. When it is desired to set the brakes, the engineer opens a valve in the air hose, reducing the pressure. At once the air in each car reservoir forces open a control valve and exerts its pressure through an air cylinder against the brake shoes, forcing them against the wheels. When the engineer restores the pressure, the control valve is reversed and the brakes are released.

The Gas Engine.—Just as the invention of the stationary steam engine led to the locomotive, so the invention of the gas engine led to the remarkable modern development of the automobile. In the steam engine, water is heated to steam and this steam drives the piston back and forth. The problem in steam engines is that of keeping the cylinders hot, so that the admitted steam will not cool and lose its power before it fully expands. In the gas engine, the fuel used is burned right in the cylinders, and the real problem has always been to keep the cylinders cool and so to prevent the expanding of the metal pistons to a point where they would bind in the cylinders.

In the ordinary gas engine, the explosive gas is admitted on one side of the piston, is compressed by the piston itself and then is exploded by an electric spark. The force of this explosion drives the piston head violently back, turning a heavy wheel whose momentum drives it forward again. In automobile engines, cylinders usually are connected in series. A study of the four-cylinder motor will give an idea of the working of the gas engine.

The four cylinders are set in a line. Each cylinder makes four different kinds of strokes: the intake stroke to draw in new gas; the compression stroke; the explosion, or power, stroke; and the exhaust stroke to force out used gas. Two of these strokes

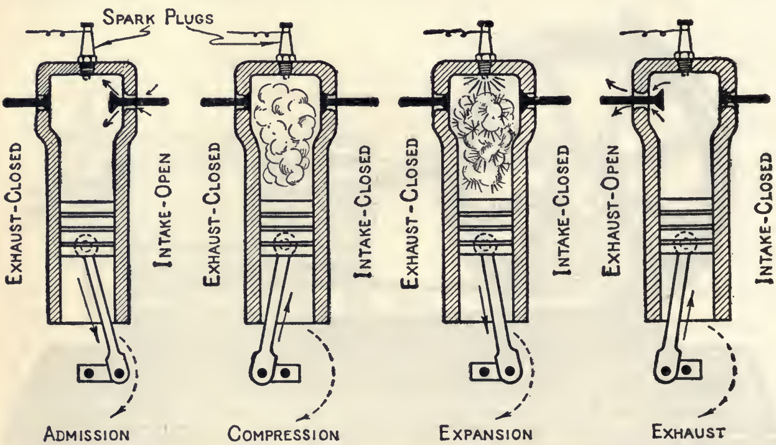


A Stationary Gas Engine

are made in one direction and two in the other. Such an engine is called a four-cycle engine.

Gasoline entering drop by drop from the gasoline tank into the carburetor, or mixer, vaporizes and is mixed with air to form a highly explosive mixture. This mixture is drawn into each cylinder above the piston. On the first upward stroke it is compressed. At the proper instant, by means of a timing device connected with the cylinder, an electric current is sent through a spark plug in the head of the cylinder and is forced to jump a tiny gap, thus causing a spark which explodes the vapor. The explosion

drives the piston back in a power stroke. On the next stroke upward the exhaust valve opens so that the piston forces out the burnt gas. On the next downward stroke the exhaust valve closes, the vapor valve opens and vapor is drawn in by its own expansion and by the vacuum created by the downward movement of the piston. On the next upward movement the vapor is compressed and the process continues. Each piston makes four strokes for each explosion of gas, but no two explosions occur at the same instant. Thus, as speed increases, there is a fairly continuous application of force to the drive rod or crank shaft, with which the pistons are connected.



THE FOUR STROKES OF A GAS ENGINE

When the engine runs at high speed explosions are very rapid and the heat developed is extreme, often exceeding 3,000 degrees F. To keep this heat down, most gas engines have water jackets built around the cylinders and connected by tubes with the radiator at the front of the automobile. The water in the jacket is heated by the cylinders and then circulates, either by convection or by means of a force pump, through the radiator where it passes through many small tubes and is cooled by the air. It then returns to the cylinders to relieve them of more heat. A fan, set in front of the motor, is also used to air-cool

the radiator and cylinders. In fact, some motors are wholly air-cooled by means of large fans which suck air past the cylinders whose exteriors are so shaped as to give a large radiating surface.

The motions of the pistons in the gasoline motor are carried to a crank shaft and changed from back and forth motion to circular motion. By means of a clutch, which is a device for connecting or disconnecting parts of machinery at will, this motion is continued through a transmission rod, or main shaft, to the rear axle and thence to the rear wheels. Speeds are in part regulated by the gear shift, which is a collection of interlocking cog wheels of various sizes. By means of the gear shift, great power can be applied at slow speed or, by shifting to other combinations, less power at higher speeds. Most gear shift systems allow three speeds forward and one back.

The motor constitutes the power plant. The various connections which drive the car constitute the transmission system. In addition, there is an electric system, consisting of the generator which charges the battery while the motor is running; the battery itself for the storage of electricity; the wiring and spark plugs to fire the gasoline; the lighting system; and the self-starter, the motor which cranks the engine for starting.

There are other systems as well, such as the control system which causes the car to stop and to change its direction. It includes the steering device and the brakes. There is also the cooling system, consisting of the radiator, water pump and entire circulatory apparatus for keeping down heat. There is the carburetor system, which consists of a vacuum tank to draw gasoline from the fuel tank, and a carburetor in which gasoline is mixed with air to form an explosive vapor.

The gasoline tractor is also finding a steadily wider use. It is employed in road construction and in hauling loaded cars. In many sections it is widely used in agriculture. A modern tractor will draw a series of plows or harrows, preparing many acres of ground a day for crop planting. It hauls reapers, harvesters, and cultivators. On larger farms where the soil is free from boulders, it is rapidly taking the place of horses.

Electric Lines.—The first public service lines for carrying passengers within cities and towns used horse-drawn stages. These stages were succeeded by rail lines on which street cars were drawn by horses. After the development of electrical power, electric cars took their place. These cars draw their current either from an overhead wire running to a distant power house or from a charged rail. In the latter case a plow, or metal bar, reaches from the car down through a continuous slot between the tracks and connects with the rail underneath, which carries the current. In subways, and on elevated lines and some interurban lines the electric cars draw their current from a third rail located beside the tracks.

The motor of an electric street car is much like an ordinary electric motor. The armature is set on a revolving axis and connected with the drive wheels of the car. When current from the feed wire is passed through the machine, the poles of magnet and armature are oppositely charged and the attraction between them starts the revolution of the armature. The motor commutator maintains this opposite charging and revolutions continue. By means of a control box the motorman is able to regulate the power and the speed of the motor. The circuit of the current is completed through the track, each rail being welded to the next.

Certain of the steam railway lines also are being partly electrified. Electric locomotives take the place of steam locomotives around terminals in certain cities and in hauling trains through tunnels, and one transcontinental line is electrified for a stretch over the high western mountains.

Electric locomotives are exceedingly powerful. The advantages of electric over steam power on through rail lines are freedom from coal dust, ease of motion, ease in starting heavy loads, easily regulated power, and the use of natural water power along the lines to supply electricity.

Modern Motor Transportation.—The gasoline motor is making great changes in modern transportation. Today millions of automobiles are used for pleasure and for business. Thousands of trucks deliver goods and haul supplies. In addition, motor freight and passenger lines form a network across the

country. Their trucks and buses run on fast regular schedules. Today it is possible to travel on bus lines, comfortably and at moderate cost, from coast to coast.

Motor transport lines and private automobiles have seriously affected electric and steam railroads. Bus lines are taking the place of electric street car lines. Railroads carry fewer passengers than even a few years ago, and carry less freight on short hauls, as motor trucks now collect and deliver freight directly at

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AN ELECTRIC LOCOMOTIVE

The power of a distant waterfall pulls this train over the mountains.

the store or factory. In fact, for self protection, railroads are beginning to establish their own motor lines for short hauls and to replace branch rail lines.

SUMMARY

It took thousands of years for early man to progress beyond the use of drags, pack horses, and carts for transportation.

Carts and four-wheeled wagons with spoked wheels formed the main means of travel for centuries.

Improvements in transportation have always been coupled with improvements in roads. Earth roads, corduroy roads, and stone blocks have given way to broken stone roads and finally to the modern cement road.

Bridges have developed from logs thrown across the streams to immense frame structures and to suspension bridges covering wide spans.

Great progress in land transportation followed the invention of the steam engine. It made the locomotive possible. Steam rail transportation has become a great factor in our national development during the last century.

In the steam engine steam is admitted alternately to opposite sides of a piston in a cylinder where its expansion drives the piston back and forth.

In the gas engine the piston is moved by the explosion of gasoline within the cylinder itself.

The gas engine led to the invention of the automobile, now one of the greatest factors in modern transportation.

The dynamo led to the invention of motors which change electric energy to the energy of motion. Now much machinery is run by motors.

The electric motor was early adapted to the running of street cars and is now used in immensely powerful engines for pulling freight and passenger trains.

Fact and Thought Questions

1. Why have good highways made nations stronger?
2. Name three ways in which good transportation facilities aid in the development of a country.
3. How has the automobile caused the extension of good roads?
4. Describe the structure of (a) macadam, (b) concrete, (c) asphalt, roads.
5. Name several steps in the development of land transportation.
6. When was the first railway across the country completed?
7. In what ways are railways superior to stage lines?
8. Name the essential parts of a locomotive.

9. How is the steam in a locomotive generated and put to work?
10. What purpose is served by weighting the drive wheels of a locomotive?
11. Suggest ways in which steam power helps us.
12. Why are roads and railways "banked" or raised on the outer side of curves?
13. How are steam trains controlled?
14. In what ways does the gasoline motor differ from the steam engine?
15. Describe the operation of the gasoline motor.
16. Name several systems in the automobile and describe the purpose of each.
17. Name some advantages of the automobile over the trolley car.
18. Why does an automobile stop quicker with four-wheel brakes than with two-wheel brakes?
19. How do automobiles serve steam railways? How do they lessen their traffic?
20. Suggest reasons why the auto bus is taking the place of the suburban trolley lines.
21. Why are gasoline-driven vehicles and machines replacing those drawn by horses?
22. Outline briefly the working of an electric motor.

Projects

1. Study an automobile, with an instruction book if possible, or study a dismounted car at a service shop and locate and trace the main parts and systems.
2. Study a bridge in your neighborhood. Make a sketch of it. Determine the materials of which it is made. See how the ends are supported.
3. Secure a toy train and track. Test the train under differences of grade, load and curve. List your observations and explain them.

Outdoor Observation

1. Watch the construction of macadam, asphalt and concrete roads and record how each is made.
2. Observe and record different uses of gasoline motors.
3. Observe a steam locomotive at rest and in motion. Try to identify the main parts. Study the main connections.

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CHAPTER XX

TRANSPORTATION ON THE WATER AND IN THE AIR

By making possible fast ocean-going ships, rapid railway trains, and high-powered aircraft, science has reduced the time formerly required for travel so that nations separated by great distances have become neighbors. Today the products of the whole world may be drawn upon to meet the needs of any people.

Within recent years, new highways have been opened in the air above us, and already man may travel where he will, over all obstructions, at speeds faster than those of the swiftest birds. By new and better transportation on land, on sea, and in the air, the whole wide world is now being knit closer together.

In the early days of man, large bodies of water set a limit to his travels. He might swim or wade across a small stream but larger ones held him back. Even after he had discovered means of crossing the larger streams he was helpless before great lakes and the vast oceans. It was only very gradually that he was able to develop means of getting across to the lands that lay beyond.

Perhaps man's first craft was a floating log on which he sat astride and paddled with his hands or with a broken branch. After a time, in order to carry heavier loads, he bound several logs together and formed a raft, using a pole or a paddle to propel it. Later he learned to hollow out the inside of a log by fire and by rude tools, and so fashioned the dugout, which was a forerunner of the canoe and of the small boat.

Gradually man learned to make framed ships of boards, and to change his paddles to oars. These framed ships grew in size with increased demands for transporting people and goods, and with them the oars increased in number. For many centuries large ships, called *galleys,* were used for sea traffic. These were driven by oars of great length, often arranged in several rows or banks, one above the other, and manned by slaves.

Sails have been used for about six thousand years. At first they were only for small boats. As they were fixed in position they were dangerous in gusts of wind and useless if the wind came from the wrong direction. Gradually man learned to make sails that could easily be drawn up or lowered to meet the wind conditions. By degrees these sails were more carefully designed and were made adjustable to winds so that vessels could sail by

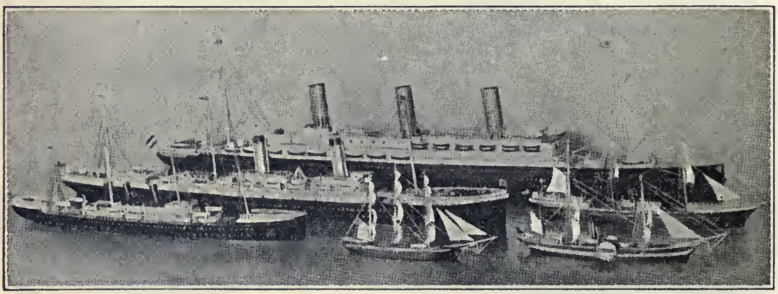
Save "Old Ironsides" Fund.

"OLD IRONSIDES" UNDER FULL SAIL
U.S.S. Constitution, our most famous square-rigged ship.

wind power even when the wind was not in the direction in which they wished to go. Sea captains learned to sail by *tacking,* zig-zagging by alternate moves first in one direction and then in another, in order to take advantage of the wind. Masts and rigging gradually developed further, and sails increased in number and became more intricate until vessels like the famous "Old Ironsides" came into being. These carried a wonderful mass

of sails, hung largely on cross bars on the masts, forming what is known as square rigging. With their several towering sail masses and their splendid design, these ships were capable of high speed.

The invention of the mariner's compass, the increasing knowledge of oceans and other great bodies of water, and the development of larger ships making faster time, sent vessels farther and farther away from the land. This led to the discovery of new lands beyond the seas and to increasing commerce with distant countries. Commerce and travel, however, were dependent upon winds. Periods of calm or light winds often delayed ships for weeks. Great storms frequently wrecked the rigging of sailing vessels, even if the ships themselves survived, and ocean travel was not only slow but dangerous. As time went on, science made possible distinct advances in water travel.



Popular Mechanics Magazine.

THE DEVELOPMENT OF SHIPS
Progress in shipbuilding during a century and a quarter.

The Steamship.—The invention of the stationary steam engine led to experiments by Robert Fulton and to his final success in connecting an engine with paddle wheels, so that steam power would drive them and propel a boat to which they were attached. The first practical steamship, the *Clermont,* was the result. On October 17, 1807, this little vessel traveled the 150 miles from New York to Albany at a rate of five miles per hour, independent of winds.

Rapid improvement in propelling machinery caused rapid increase in the use of steamships. In 1839 the screw propeller was

invented and now has taken the place of paddle wheels on vessels of large size. In screw propelled boats, a great metal shaft extends from the engine through the back, or stern, of the boat below the water level. To this shaft, on the outside of the boat in the water, the screw is attached. It consists of two or more metal blades somewhat resembling the blades of an electric fan. When the shaft is revolving, the screw blades, set at an angle, drive the ship forward by their pressure against the water.

Vessels now use oil as well as coal for fuel, to generate steam and sometimes electricity with which to drive the propellers. Very small boats or launches often use gasoline or electric motors. Many of the newest and finest types of steamships are driven by *steam turbines.* In the steam turbine, series of blades are connected with the propeller shaft within the vessel's hull and, of course, revolve with it. These blades alternate with fixed blades on a casing that surrounds the shaft. Both sets of blades increase in size from the point nearest the boiler to the end of the turbine. Steam is admitted at the small end and, by its pressure on the curved blades of the shaft, tends to revolve it and so turns the propeller. The steam is then deflected to the stationary blades of the casing and is again deflected to the next series of shaft blades and so on. As the steam gradually expands, it is given a larger and larger surface upon which to exert pressure.

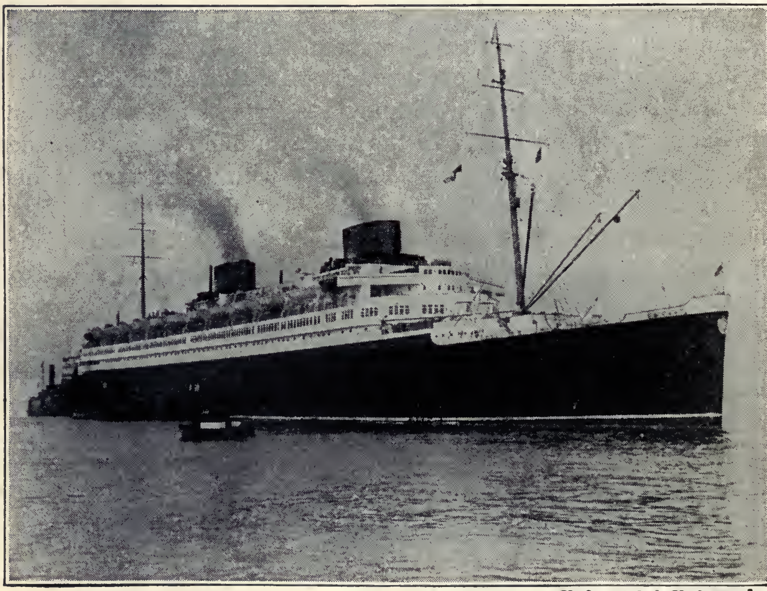
Steam turbines develop tremendous power and very high speed over long continued periods. Thus far, turbines have not been invented that will reverse direction. Consequently, great ships using the turbine system usually carry several turbines for forward motion and other turbines for reversing direction.

The development of the iron and the steel industries led to the making of vessels from these metals. Such ships are larger, stronger, and are capable of carrying much greater cargoes than wooden ships.

The question naturally arises, "Why does a metal ship float?" Any object will float if it weighs less than an equal volume of water. A cubic foot of water weighs 62½ pounds. A cubic foot of wood weighing 50 pounds will float, because it is not

heavy enough to displace an equal volume of water. A cubic foot of iron, on the other hand, weighs 468 pounds and so will sink.

If, however, we rolled this cubic foot of iron into a thin metal sheet and shaped it into an iron box 6 feet long, 4 feet wide and 1 foot high, we would have a box with a volume of 24 cubic feet. The iron would still weigh 468 pounds, but in order to



Underwood & Underwood.

THE EUROPA, A GREAT OCEAN LINER

On her maiden voyage the *Europa* covered the distance from France to New York, approximately 3100 nautical miles, in 4 days, 17 hours, 6 minutes. She is driven by steam turbines.

sink it would have to displace 24 cubic feet of water, which weighs 1500 pounds. It would, therefore, float and support a cargo of over 1000 pounds. Similarly, in a metal ship, the metal is shaped into a hollow hull which weighs much less than an equal volume of water.

Ship designers are able to calculate to what point the vessel's *hull,* or body, will sink in the water. That is the *water line* and

is often painted on the ship's hull. A second line above it often shows how much more the vessel can be lowered in the water with safety when loaded. Then the amount of cargo weight can be determined. Our greatest modern liner, 950 feet long, can carry 30 thousand tons of load and can cross the Atlantic in about five days.

Experiment to Show Why a Metal Ship Floats.—Procure a tin biscuit box. Weigh the box. Place it on the surface of water and notice that it floats. Now hammer the sides of the box out flat until it is merely a straight piece of tin. Weigh it again. Does it weigh as much as it did when it was in the shape of a box? Place it on the water. Does it float? Is the volume of the tin as great as was the volume of the box? How does this explain the floating of a metal ship?

Popular Mechanics Magazine.

A Modern Submarine

The Submarine.—Man has not been content simply to sail on the surface of the water. Early in the history of ship building he began to experiment with craft that would travel under water. The first practical submarine, however, was not invented until 1775, when one was built by David Bushnell of Maine. The modern submarines are developed from inventions of John Holland, another American. His first submarine was 60 feet long. Today, there are submarines of approximately 400 feet in length that approach in size and power many a modern powerful surface steamship. The submarine is built to weigh less than an equal volume of water. Therefore, under normal conditions, the vessel rises somewhat above the surface of the water. It is equipped

with tanks inside, into which sea water may be admitted by valves. If enough water is added, the vessel goes below the surface. Since, however, water pressure increases rapidly with depth, a submarine cannot descend too far without danger of crushing. When the water is pumped from its tanks the submarine rises.

A modern submarine is crowded with intricate machinery. There are, for example, oxygen tanks and apparatus to purify air, gauges to indicate depth below the surface, pumps and valves to regulate the depth, oil engines to propel the ship on the surface, electric motors and storage batteries to drive it when submerged, and appliances to handle weapons if used in war.

Stability of Ships.—The safety and value of a ship depend largely on its design and on its *stability.* Stability is capacity to stay upright, or to recover an upright position instead of rolling over. In general, stability is increased by having all possible weight in the boat placed low and near the center. There are five main factors in making boats stable: having wide beam, or great width; building air chambers into the sides; weighting the keel, the lowest timbers or plates in the ship's bottom; placing ballast, or heavy material, low in the center of the vessel's hull; using a centerboard, a thin, weighted blade extending below the keel. Sailboats are built with centerboards or weighted keels to overcome the tendency to overturn, due to the wind pressure on the sails.

Ocean Routes.—Gradually from long experience, steamships have come to follow regular paths or lanes. These lanes are many, many miles in width. They represent the courses which give greatest freedom from storm, fog, and danger of icebergs. These traffic lanes are not the same at all seasons of the year. For example, in crossing the Atlantic, ships take a more northerly course in summer than in winter.

Most governments have charted their coast lines, marking all rocks, reefs and shallow areas so that sea captains may be guided in keeping their ships in safe waters. In addition, governments establish and maintain lighthouses at points of special danger, and buoys, or painted posts or floats, to mark the channels of

rivers and the entrances to harbors. In addition, most ships are now equipped with radio apparatus so that if they are endangered in any way they may call for help. There are also many modern inventions that safeguard travelers in case of disaster. Sea travel today is infinitely safer than ever before.

Instruments Used in Navigation.—In the navigation of ships the compass, of course, plays an important part. The modern compass is very complicated in structure, in order to make it reliable on any ship, and in order that it may always occupy a horizontal position no matter how much the ship rolls.

In sea travel, due to winds and tide and other factors, the actual position of a ship out of sight of landmarks is often unknown unless accurately determined by instruments.

To locate the position of a ship at sea two instruments are commonly used. One is the *chronometer,* a clock which keeps accurate time. A ship usually has two chronometers, one telling actual Greenwich time, and the other telling the ship's local time, determined at noon of each day as the sun reaches its highest point in the sky. By comparing the times of the two chronometers the ship's longitude can be determined, as each hour of difference in time indicates 15° difference in longitude from Greenwich.

Latitude is determined by a rather difficult process involving an instrument, called a *sextant,* for making observations of the sun which are then compared with certain tables in the standard *Nautical Almanac.* The sextant can be used only when the sun is visible. It measures the angle formed by lines running from the position of the observer to the sun and to a point on the horizon directly beneath. By means of the almanac table, this angle is translated into terms of latitude.

The speed of a ship is determined by a form of propeller dragged after the ship on a cable. The propeller revolves as it is pulled through the water. This apparatus is connected through the cable to a dial on which it records its revolutions in terms of miles. This instrument is known as the taffrail log. It can be best understood if we think of it as acting much as does the familiar speedometer of an automobile.

The Balloon.—For centuries, man has sought to make some form of craft that would float in the air. These efforts came to nothing until about 1783, when the Montgolfier brothers made the first balloon of which we know. They made a bag somewhat more pointed than the modern balloon and filled it with heated air. It went up and satisfied them that they were on the right track. In further experiments they attached a basket to the bag and sent up a lamb, a duck and a rooster. These were carried up and then came safely back to earth. Later, with the balloon held captive by ropes, first one person and then two ascended and remained aloft for nearly half an hour. As in all fields of science, steady improvements have been made in balloons and other air craft.

A standard balloon consists of an enormous bag of cotton or silk cloth, coated with a rubber preparation to prevent leakage of gas. Over the bag is carefully fitted a rope net to the lower strands of which a light-weight basket is attached to carry passengers.

The power of the balloon to lift weights depends upon the fact that it is filled with gases which are lighter than air. Consequently, they tend to rise and are able to lift a weight nearly equal to the difference between the weight of the gases in the balloon and the weight of a corresponding volume of air. Originally, hot air, which is lighter than the ordinary air, but which cools rapidly, was used. Then coal gas was employed, and after that hydrogen. These two gases are highly dangerous because extremely inflammable. Helium gas, non-inflammable and almost as light as hydrogen, is now being used to some extent, although the supply is limited.

Before a balloon starts on a flight, the collapsed bag is connected with the gas tanks and gas is admitted until the bag is partially inflated and begins to tug at its moorings. Then the basket is attached and the mooring ropes are freed. The bag becomes fully inflated as the balloon mounts, because the atmosphere becomes lighter and the balloon gas tends to expand rapidly. When the air becomes so light as to equal the lightness of the gas in the balloon, plus its load, the balloon stops rising. It may be

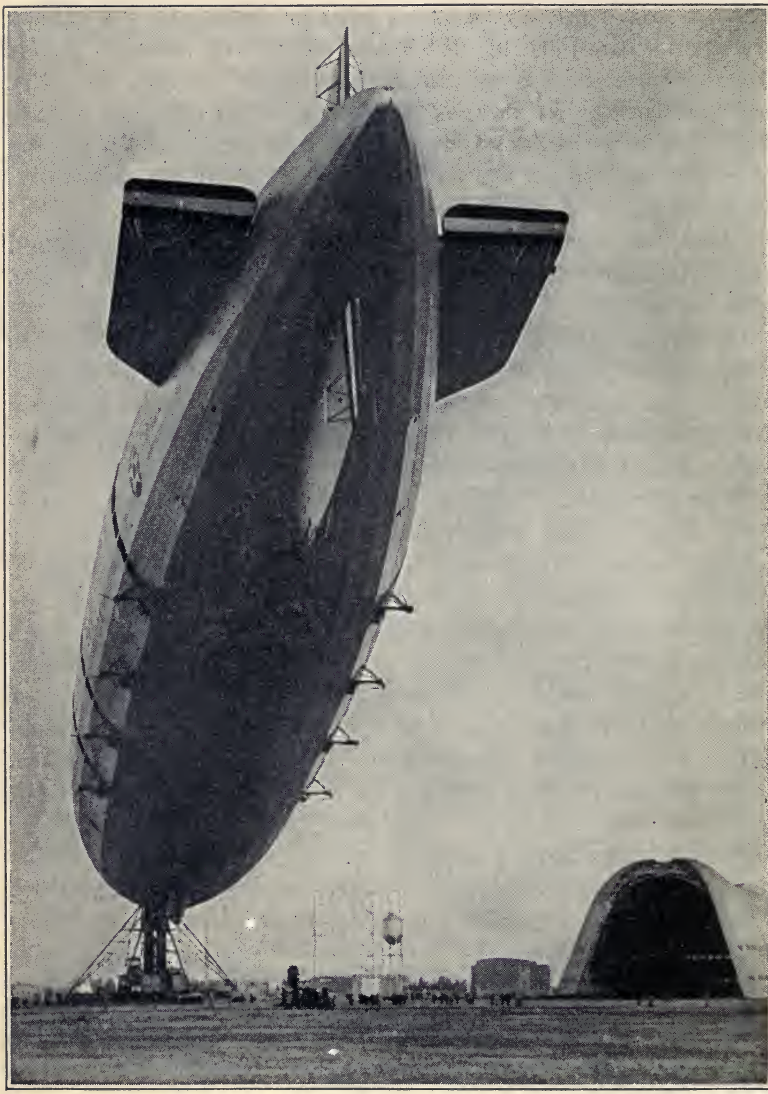
made to rise higher by throwing out sand ballast that is carried in bags for the purpose. To make the balloon descend, gas is released from the bag by means of a valve. In fact, the valve acts automatically if the gas pressure gets too high. In case a rapid descent is necessary, a pull on a cord attached to a ripping panel arranged in the top of the balloon bag will rip the balloon open and allow the gas to escape.

As a rule, balloons carry trail ropes which touch the ground long before the balloon reaches it, and act as a drag, or brake, upon its motion.

Except in regulating altitude, the navigator of a balloon has comparatively little control over it. It floats with the wind, consequently seeming motionless to the rider, except for its tendency to spin around. Owing to this motion, compasses are practically useless for determining direction.

The Dirigible.—With the invention of the gas motor, experiments were quickly undertaken to determine the possibility of building balloons which could be guided in any desired direction, and which could even be driven against the wind. As a result the modern *dirigible* has been developed. Dirigibles are long, pointed balloons usually carrying their covering on light aluminum frames, well braced to stand the pressure of the wind. The making of frames that are both light and very strong has been the main difficulty in dirigible construction. These covered frames are either themselves filled with gas or contain many separate compartments filled with gas. This gives them buoyancy, or floating power. Beneath the immense gas bag are attached the cabins for the crew and the big motors which supply power. There are often several motors which develop tremendous power. The dirigible airship compares favorably in length and bulk with ocean liners. The United States Navy dirigible *Macon* was 785 feet long. Many striking records have been made by dirigibles, including a trip around the world in August, 1929, by the *Graf Zeppelin,* a German passenger dirigible.

The Airplane.—Just as man has worked to invent a ship that will float in air, so he has striven for a long time to imitate the birds in flight through the air. Early attempts at airplanes



Keystone View Company.

A Modern Dirigible at Its Mooring Mast

included efforts to copy the wing beat of birds, as well as their gliding. Little success was ever reached by imitating wing motion, although many studies of flying birds, photographic and otherwise, were made for years. Far more success followed experiments in gliding.

After long experimenting, Samuel Langley, then director of the Smithsonian Institution of Washington, worked out a model for a plane, with two wings and a propeller, that flew successfully in a wide circle and landed safely.

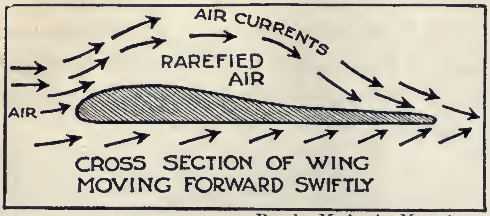
The Wright brothers of Ohio, who had been experimenting in the same field, studied the results of the Langley experiment. They made special experiments with gliders to determine the effect of wind upon them, and then constructed larger gliders with considerable wing spread. They continued their experiments with these until they reached a point where they had a glider that would remain in the air for quite a time and support a person who controlled it. They finally built an airplane equipped with an engine and two propellers in which the first practical flight of an airplane under power was made. That was in 1908. Thereafter, improvements came rapidly, and during the World War period, and since, the airplane has become a wonderful machine, capable of sustaining flights of many hours, of reaching enormous heights, and of attaining terrific speeds. Already an altitude record of about eight and one-half miles has been established, and a speed record of over 400 miles per hour.

Popular Science Monthly.

THE FIRST PRACTICAL AIRPLANE
Orville Wright's famous flight in 1908

The practical commercial and public service use of airplanes is assured. Many airplanes fly on regular schedules, both in this country and abroad, carrying numbers of passengers. The United

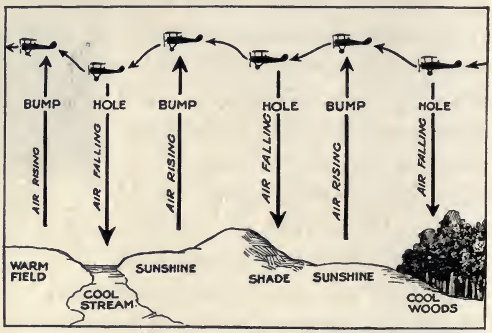
States Post Office Department has established, and is rapidly extending, an air mail service which is making remarkable records for efficiency and reliability. This service has more than cut in two the time necessary for transmission of mail between distant points.



Popular Mechanics Magazine.

WIND PRESSURE ON AN AIRPLANE WING

While the balloon craft depend for their ability to stay aloft on a gas which is lighter than air, airplanes remain aloft by utilizing the pressure of air itself, although the machines are far heavier than the air. The main supporting surface consists of the wings, which have a very large area, with a convex surface on the upper side and often a concave surface on the lower side. There are *monoplanes,* or airplanes having one general supporting plane; *biplanes,* having two planes; and *triplanes* with three.

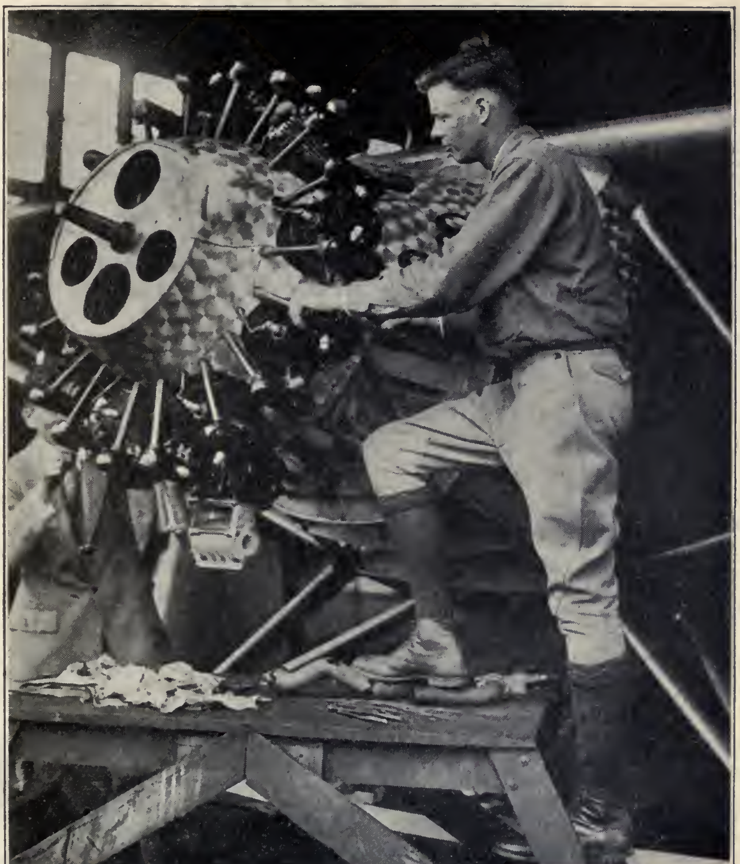


Popular Mechanics Magazine.

AIR HOLES ON A SUNNY DAY

The wings are so shaped that when slightly tilted into the wind the wind pressure strikes into the lower surface and tends to force the plane upward, while the convex surface on the upper side tends to throw the wind off and forms a partial vacuum. The machines are kept on an even keel by the operation of little hinged surfaces at the rear of the wings. When one of these surfaces is tilted up it causes the air to exert great downward pressure on the wing to which it is attached, and the entire plane is tipped in that direction. When the surface is tilted down, the plane tips in the opposite direction. They also have elevating

COL. CHARLES LINDBERGH *and* "THE SPIRIT OF ST. LOUIS"



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IN May, 1927, Charles Lindbergh flew "The Spirit of St. Louis" from New York to Paris, 3,610 miles, in 33½ hours. He went alone. In welcoming him home, the President of the United States said: "Some of the qualities noted by army officers who examined Col. Lindbergh for promotion are as follows: Intelligent, industrious, energetic, serious, deliberate, stable, efficient, frank, modest, congenial, a man of good moral habits and regular in all his business transactions. One of the officers expressed his belief that the young man would 'successfully complete everything he undertakes.' This reads like a prophecy. . . . It is our great privilege to welcome back to his native land, on behalf of his own people, who have a deep affection for him, and have been thrilled by his splendid achievement—a colonel of our republic, a conqueror of the air and strengthener of the ties which bind us to our sister nations across the sea."

THE CONQUEST OF THE AIR

In 1783, the Montgolfier brothers, of France, constructed a balloon in which two men made a successful ascension. This was man's first flight in air.

In 1901, the Wright brothers, of Dayton, Ohio, succeeded in gliding through the air in a light, motorless framework equipped with a double pair of wings.

In 1908, the Wright brothers built a heavier-than-air machine equipped with a motor and two propellers, which flew for more than an hour. This was the first practical airplane flight.

In 1909, Louis Bleriot, of France, successfully crossed the English channel in a monoplane.

In 1919, the British dirigible balloon R-34 successfully crossed the Atlantic ocean twice.

In 1919, the United States seaplane NC-4 successfully crossed from America to Europe, stopping at the Azores.

In May, 1927, Col. Charles Lindbergh of the United States Officers' Reserve Corps flew a monoplane from New York to Paris, 3,610 miles, in 33½ hours.

In August, 1929, the dirigible Graf Zeppelin made an around-the-world trip from Friedrichshafen, Germany, 19,500 miles in 21 days, 7 hours, 34 minutes.

In November, 1929, Commander Byrd of the United States Navy flew an airplane from his camp on the Antarctic continent to the South Pole and back, 1600 miles in 10 hours, 26 minutes.

In April, 1931, Francisco Agello, of Italy, flew a racing monoplane at the rate of 423 miles per hour.

In July, 1933, Wiley Post, an American, made a 15,596-mile flight around the world in 7 days, 18 hours, and 49 minutes.

In September, 1933, M. G. Lemoine, of France, flying a specially equipped airplane, reached a height of 44,819 feet, or about 8½ miles.

In September, 1933, three Russian aviators, Prokofief, Birmbaum, and Gudenoff, in a sealed aluminum gondola slung under a gigantic balloon, rose to a height of 11.8 miles.

planes, horizontal planes at the tail of the machine controlled by the aviator. If the elevating planes are turned downward air pressure on the lower surface tends to throw the tail up and thus head the machine down. If the elevating planes are turned upward the air pressure on the top tends to drive the tail down and to cause the head of the plane to lift. A vertical rudder at the tail steers the machine.

Wright Aeronautical Corporation.

A POWERFUL RADIAL MOTOR

Such motors are used in Navy scout planes and in certain other airplanes.

Airplane bodies are modeled after the body of a bird. That is, they are heavier and larger in the front and taper back to the tail.

For driving power, gasoline motors are used, sometimes several being employed. The individual motors may be of six, eight, or more cylinders. One type of rotary motor consists of nine cylinders.

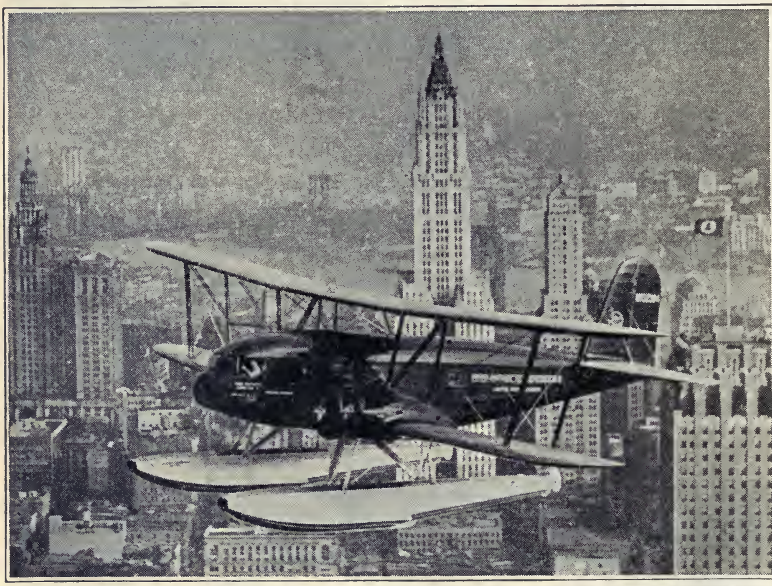
For landing purposes, the ordinary airplane has a wheel rigging. For landing and taking off on a snow surface in cold regions, runners are sometimes used. For landing and taking off from water, *pontoons,* or air-tight, boat-like floats, are used, capable of supporting the full weight of the machine. When these are used the machine is termed a *hydro-airplane.*

Keystone View Company.

AN ALL-METAL PASSENGER MONOPLANE

When the plane is in flight, the wheels are pulled up to reduce air resistance.

Aviators are equipped with *parachutes* for use in case of accident. These are umbrella-like cloths, to the edges of which many cords are fastened. The other ends of these cords are attached to a waist belt. At ordinary times parachutes are carefully folded and packed into small space, so arranged, however, that they will be released when a cord is pulled, and will open by air pressure. The aviator leaps from his machine and pulls the cord after he has



Keystone View Company.

ADMIRAL BYRD'S ANTARCTIC BIPLANE, OVER NEW YORK CITY
The pontoons enable the plane to light safely on the water.

started down, the pressure of the air in the open parachute serving to check his fall.

SUMMARY

The floating log, the dugout, the raft, and boats rowed by oars were early used in water navigation. Sailing ships followed.

The mariner's compass made possible long voyages, led to discoveries of new lands, and increased the demand for ship transportation.

The first practical steamship was built in 1807. The early ones were driven by paddle wheels, the later ones by propellers, or metal blades, whose rapid revolution drove the ship forward by water pressure.

Some immense ships today are driven by steam turbines, in which the generated steam expands against movable and fixed blades in a casing surrounding the propeller shaft.

The invention of iron and of steel ships led to the building of great and strong vessels. Such ships float because their weight is less than the weight of an equal volume of water.

The stability of ships, or their ability to keep from overturning, is secured by width, or beam, by fixed ballast, by weighting the keel, by air chambers, or by centerboards.

The safety of ships has been greatly increased by strength of structure, by modern instruments of navigation, by charts of the coast lines and harbors, by lighthouses and buoys, and by wireless communication.

Early air navigation was by balloons, or bags of cloth filled with hot air. These rose because the heated air was lighter than the outside air. Later, coal gas and hydrogen gas were used but were found dangerous because they were very inflammable. Today in the great airships non-inflammable helium gas is coming into use.

Balloons can go higher by dropping out ballast, or lower by releasing gas. They cannot be driven or guided.

The dirigible developed from the balloon. It is a long, pointed balloon, often built around a light metal frame. Motors and cabins are attached to the frame and suspended beneath the balloon. Dirigibles may be driven at high speeds and guided on a course.

Airplanes are the result of years of effort to enable man to fly. They followed long studies of flights of kites and birds. Langley's model—a miniature machine—was the first plane to fly under power. The Wright brothers made the first practical airplane.

Modern airplanes are run by gas motors having six or more cylinders. Some planes carry several motors.

Airplanes are held aloft by air pressure against the under side of the wings, which are usually concave. The convexity of the upper side tends to shed wind pressure and to cause a partial vacuum above them. Airplanes are guided by vertical rudders and are headed up or down by raising or lowering horizontal tail planes.

Monoplanes have one supporting wing, or plane, biplanes two, and triplanes three.

Ordinary airplanes have landing gear fitted with wheels. Seaplanes, or hydro-airplanes, carry pontoons, or boat-like floats, which support them on the water.

Airplanes are rapidly finding a place in the transportation field. There are already a number of regular passenger lines. The United States is rapidly extending a very successful airmail service.

Fact and Thought Questions

1. Outline briefly the development of water craft from early times until now.
2. Why does a metal ship float?
3. Name several advantages of a steamship over sailing vessels.
4. Define stability. State four ways in which a ship's stability is assured.
5. Why is the cargo of a ship fastened in place so it cannot shift?
6. Define (a) propellers, (b) steam turbines.
7. Suggest some advantages of the propeller over the paddle wheel.
8. Complete this statement: The invention of the —— made possible sea voyages out of sight of land.
9. Why is it necessary for a sea captain to take the "position" of his ship at fixed intervals?
10. Why do ships tend to follow regular highways? What conditions govern the choice of these?
11. What is a submarine? How is it submerged and raised?
12. Why is it safer to travel by sea now than it was a century ago?
13. Why cannot a submarine go far below the surface of the water?
14. Why does a balloon mount faster when it first leaves the ground than when it is some distance up? When does it stop rising?
15. What is a dirigible? What advantages has it over the balloon?
16. What gases are used in balloons and dirigibles?
17. What is the safest and best gas thus far used in airships, and why?
18. State how airplanes are lifted, guided and propelled.
19. Can an airplane fly directly into the air? Why?

20. If an airplane motor were powerful enough, would there be any limit to the distance it could rise above the earth?
21. Name all the present uses of airplanes you can think of.
22. Why do toy balloons sometimes burst when they reach considerable heights?
23. Why is a balloon likely to descend somewhat at nightfall?
24. What is the difference between seaplanes and other airplanes?
25. Is it more difficult to sustain an airplane at an altitude of one mile than at an altitude of four miles? Why?
26. What is a parachute? How does it work?

Projects

1. Construct a balloon and fill it with heated air. Let it rise and record your observations of its movements.
2. Construct a kite. Fly it. Experiment with different cord connections to bring it at different angles to the wind. Record your findings.
3. By reference to some standard book, construct an airplane model. Test it out in the air and record your observations. Make a labeled drawing of it.
4. Construct a model sailboat by reference to some standard book. Sail it on a pool or small body of water and observe the effect of the wind upon it under different conditions. Record your observations.

Outdoor Observation

1. Examine, if possible, a sailboat and a steamship. Study their main parts and observe them when in motion.
2. Watch a kite and an airplane in flight and record your observations.

References

The Boy's Book on Model Airplanes............................*Collins*
The Romance of Air Craft.......................................*Smith*

CHAPTER XXI

ROCKS AND SOIL

In a handful of soil taken from the garden, we have the most useful manufactured product on this earth. It is not a factory product, taking shape before our eyes in a few minutes or hours, but is something that has taken ages to produce.

Plants cannot grow roots in solid rock nor can they flourish on ledge or cliff. Nature has broken up the solid rock, with air and water and cold, ground it piece by piece to powder, and moved it by flowing stream and glacier. Now it forms the basis of all soil, on which grow great forests and fertile crops—the plant life that in the end supports all living things.

Still, rock does not have to be reduced to powder to serve us. It gives us building materials and the minerals for our modern life and, by blocking streams, enables us to use the energy of falling water. In its seams and folds and fossils is written the history of much that has taken place upon and within the earth itself in past ages. The study of rock and soil carries us back to the beginning of things on this earth.

Rock is the inorganic material which forms the solid part of the earth. It extends from just under a thin layer of soil to unknown depths. Many of our best geologists believe that it extends to the center of the earth in a solid form. The loose material on the surface of the earth is sometimes called mantle rock or rock waste. This breaks up and so forms the soil in which grows most of our plant life. The soil, however, is not a pure rock waste or powder but is mixed with more or less organic matter which has come from the decay of both animal and plant bodies.

Classes of Rocks.—Rocks are divided into various classes. They are named according to the method of their formation, and are usually classified as *igneous, sedimentary* and *metamorphic*.

Igneous rocks are those which cooled from a molten mass. Ign, the Latin stem of the word igneous, means fire. Lava, the molten rock that comes from the volcano, is igneous rock. Some of the most durable rocks we have, such as granite, belong to this class. Igneous rocks never have a layer-like structure.

Sedimentary rocks are those which have been formed by material deposited in layers, usually by water but sometimes by wind. These sediments are pressed together by the weight of material that collects above them and, with the aid of certain chemicals in them that act as a cement, they are formed into a solid mass that shows a layer formation. Sandstone and shale are sedimentary rocks.

Metamorphic rocks are formed from sedimentary rocks when they become buried and are placed under high pressure due to weight of other rocks above them. The high pressure causes a high temperature, because the energy used in the pressure is changed into heat. The high pressure and the temperature cause the structure of the rocks to change very much. In some cases it is hard to tell from what sedimentary rocks the metamorphic was made. A good example of metamorphic rock is marble. This is formed from limestone under high temperature and pressure. The material in the limestone came from the shells of small animals.

Experiment to Show Formation of Layers in Sedimentary Rock.—Place small amounts of sand, gravel, clay and humus in a jar, fill the jar with water, stir the contents and allow the material to settle undisturbed. The different materials have different weights and will settle at different rates. The heavy materials will settle at once, then the lighter, and at last the very lightest. If the water is then carefully poured off and a hole scooped in the center of the material left in the bottom of the jar, layers will be clearly noticeable.

Fossils.—Sedimentary rocks often contain forms which show the animal and plant life of the time when they were made. A plant or animal body became covered with the rock-forming material and when the body decayed new rock material came in to fill the space left. Sometimes this material is the same as

the surrounding rock, but often it is of a different kind. In either case these forms, or *fossils,* can be broken out of the rock without destroying them and they show how the animal or plant looked. The study of these fossils is very interesting and scientifically valuable, as they tell us much about the early life history of the earth.

J. A. Glenn.

Fossil of a Star Fish
A rock form of a creature that lived ages ago.

Volcanoes. — Not infrequently in the history of the world the crust of the earth has been broken open by tremendous pressures from within. When this happens, terrific explosions result and dust, cinders, and molten rock, or lava, are hurled out great distances. In most cases such an eruption leaves an elevation, usually more or less conical in form, known as a *volcano,* which is sometimes the scene of later violent eruptions occurring at irregular intervals, often centuries apart.

Mount Vesuvius is perhaps the most famous of volcanoes. It is located in the densely populated region near Naples, Italy. The date of the formation of this mountain is not known, but at the time of its first recorded eruption it had lain quiet and apparently dead for centuries. In the year 63 A. D., earth tremors were felt near the mountain, and these gradually increased in frequency and violence until the year 79, when a terrific eruption wiped out three towns and thousands of lives. Other violent eruptions took place in 1631 and 1906, doing immense damage to life and property.

Volcanoes differ from other mountains in shape, for their sides are concave while those of other mountains are convex. Their size and appearance moreover are often changed during an eruption. The entire top of Vesuvius was blown off by the eruption in 1906 and its height reduced from 4,275 feet to less than 4,000 feet.

New York State Museum.

THE PERCÉ ROCK, QUEBEC
Water carved this rock.

Rocks Used for Buildings.—Among the materials which the rocks of the earth furnish for the use of man are stones for the erection of large public buildings, residences, monuments, dams and other engineering structures. The kinds of stone most popular for building purposes are granite, marble, sandstone and limestone.

Qualities of Building Stone.—According to Dr. George P. Merrill, expert on stone quarry statistics, the essential qualities of stone for ordinary building are durability, permanence of color, crushing strength and elasticity, and cheapness.

It is claimed that: "A good building stone, whatever its kind, should possess a moderately fine and even texture, with grain well compacted; should give out a clear, ringing sound when struck with a hammer, and show always a clear, fresh fracture. It should also be capable of absorbing only a proportionately small amount of water." It is difficult, if not impossible, to find a type of building stone that meets all of these conditions. A type that is durable and strong may lack permanency of color, or a type that is durable and has permanency of color may lack strength and elasticity. Then, in every type, the expense of quarrying it and transporting it may be prohibitive, even when all other qualities apparently are present.

Granite.—In all ages, granite has been regarded as one of the most durable, strongest and most desirable of building stones. It is extensively used for walls, massive masonry of dams, polished columns of buildings, and monuments. The best granites in the United States are found in the New England states, and in Virginia, Missouri, and Minnesota.

GRANITE ROCK
Hard, durable building stone.

Sandstone.—Sandstones, as the name indicates, are made up of sand grains. These are firmly cemented together by silica, carbonate of lime, iron oxide, or some clayey material. Their durability depends more upon the character of these bind-

ing agents than upon the grains of which they are composed. The grains are generally bits of quartz in various shapes, round or angular. Sometimes they are formed of fine particles of other rocks. If the binding agent is a material like clay, liable to disintegrate under the action of water from rainfall, the stones are not durable, but if held together by a material containing silica they are both strong and durable and are among the most valuable of natural building materials. The Potsdam sandstone of St. Lawrence county, New York, is a notable example of this class.

Water Running Over Sandstone

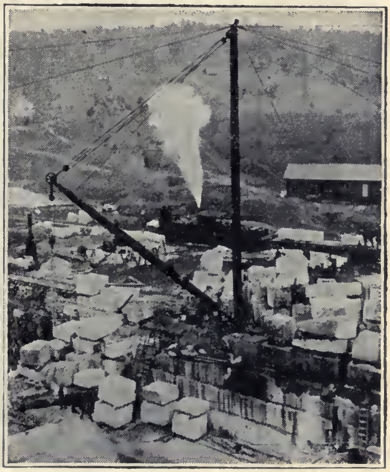
Excellent sandstones for construction purposes come from other parts of the United States. Among them are the Ohio freestones and the brown and red freestones of the Atlantic states and of the eastern slopes of the Rocky mountain system. Beds of sandstone of a red-brown and gray color, located in western New York, at Medina, provide high grade building and paving stone. Blue-gray sandstones are extensively quarried in Albany, Green, and Ulster counties in New York state, and to some extent in Pennsylvania. These are known as bluestone or flagstone and are well adapted for pavements, steps and sills.

Water Wearing Away Limestone

Limestone. — Limestones, composed mainly of the mineral calcite, form beds of rock of a gray, blue, red, or black color. These rocks usually contain some impurities, as iron, clay, or silica. Chalk is a soft limestone, commonly white, made up of the limy skeletons of minute creatures.

Limestones are as a rule not so desirable for building purposes as granite, marble, and sandstone, owing to their colors and their poor working qualities. In some sections, however, limestones are found that are good enough for building purposes. Certain ones of a white or cream color, fine grained and readily shaped, are located in southern Indiana and in northern Kentucky. Other useful limestones are found in Illinois, Ohio, Iowa, Kansas, and Missouri.

Marble.—Marble is a term which includes any limestone capable of taking a fine polish. Its most common form is that of crystalline limestone, which often contains minerals whose colors make it prized for ornamental purposes. The so-called verd antique marbles, veined with green, belong to this class. The color of marble varies from white through intervening shades of gray to black. Pink, red, and brown marbles are also quite common, the colors being due to the presence of iron oxides.



Brown Brothers.

A Marble Quarry

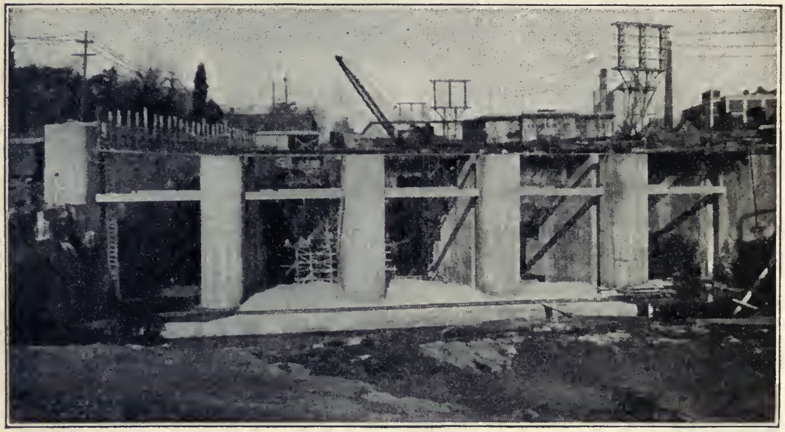
The main sources of marble in the United States are the older beds of limestone located in the vicinity of the Appalachian mountain system. The state of Vermont furnishes over 50 per cent of it. Other eastern states supply marble for building. The chief source of colored decorative marble is eastern Tennessee. The most beautiful and highly prized of all marbles is the so-called onyx marble. It was formerly found only in Egypt, Algeria, and Mexico, but is now found in California and Arizona.

Cement and Concrete.—In recent years cement and concrete have been used increasingly in place of wood, rock, and metal for important structures. Everywhere we have examples of their use in buildings, roads, bridges, sidewalks, and fence posts.

Even large ships have been made of concrete mixtures strengthened by metal.

Cement is commonly made from certain natural rocks containing a proper amount of clay and limestone, or from an artificial mixture of these two materials. This mixture is subjected to extreme heat until the clay and the limestone combine to form a compound. This product is ground to powder and is then ready for building uses.

In the powdered state cement is very dry. The addition of water causes it to set and shortly to become very hard. In fact, it becomes so hard that it is called *artificial rock.*



International Newsreel.

MODERN CEMENT CONSTRUCTION

Cement is valuable for heavy structures because it is strong, durable, easily handled and easily shaped.

Cement may be used simply with water. Usually, however, it is mixed with sand, or with sand and broken stone or gravel to form concrete. The proportions of these mixtures are generally expressed by numbers. For example, a 1-2-3 mixture consists of one part cement, two parts sand, and three parts broken stone, to which the necessary amount of water is added. Ordinarily, the sand and cement are mixed dry; then water is added and the stone finally included. Work must be done rapidly because cement begins to set almost at once. In order to give the

concrete the shape desired, molds are used. Ordinarily these are built of wood. The concrete mixture is put in them and lightly pounded or tamped into place. As soon as the material has hardened sufficiently the wooden molds are removed.

In the case of large structures, or of those subjected to heavy strain, additional strength is often given by placing metal rods within the concrete masses.

Ore and Metals.—Metals are among the most common materials used in this scientific age. Iron and steel are employed everywhere in building construction. They also form a large part of most machines. Copper, tin, gold, and silver are familiar to us from their many uses in the modern home. Some metals are found in their natural state either in veins or in cracks of rock masses. Most, however, are found thoroughly mixed with rock-like material. Rock material containing metal is called *ore*.

Brown Brothers.
UNLOADING IRON ORE

Gold occurs in veins of quartz and in some gravel deposits. To extract gold from quartz and make it available for use, the quartz must be crushed and then specially treated to remove the gold. Silver is often separated from its ore by electric processes.

Iron ore, which generally occurs in great masses, is excavated by machinery and shipped to iron or steel mills. Here it is mixed with varying amounts of limestone and coke, according to the quality of the ore. The mixture is dumped into large steel containers lined with fire brick, called *blast furnaces.* The coke is then fired, the draft being supplied by the forcing in of heated air at the base. During this process, called *smelting,* the lime from the limestone combines with the impurities of the ore to form *slag.* The heavy iron, melted by the heat, settles beneath the slag and is drawn off and run into molds to harden. It is then called *pig iron.* This iron must still be treated by other processes

before it is converted into the ordinary iron of commerce or into the stronger structural steel. The slag, also, is drawn off while in a liquid state and later is used in manufactures of different kinds. From some slags a good quality of cement is made.

FILLING MOLDS WITH MOLTEN METAL

Origin of Soil.—We are all familiar with soil. We know that it is necessary to the growth of plant life, but few of us know what it actually is. Soil is composed of both inorganic and organic matter. The inorganic part is formed by the weathering, or breaking up, of rock into very small particles by water, wind, glaciers, ice, air and, to a lesser extent, by plants and animals. The organic part of soil is derived from plants and animals.

Water.—Water erodes, or eats into, rock. The softer the rock the more rapidly the water washes away particles. During heavy storms, torrents rush down the sides of mountains often bringing masses of stones. Year in and year out these rub against the rock surface of the mountains and gradually reduce a large

U. S. Geological Survey.

NATURAL BRIDGE, VIRGINIA

Water has worn away the rock and ground it to soil.

amount of it to small particles which become a part of the soil. Even slow running water causes more or less erosion. Such great rivers as the Colorado have cut deep canyons by the gradual

wearing away of solid rock. The particles carried away by the water have been deposited elsewhere as part of the soil. The gorge at Niagara Falls was formed by the gradual erosion of rock. Water gets into crevices in rocks and freezes, breaking off small particles. This is an important factor in making soil.

Glaciers.—In all parts of northern United States and in other countries there are found evidences of ancient *glaciers,* or ice sheets. Ages ago these great masses of ice and snow covered a vast section of the northern hemisphere. They moved like immense rivers, except that the motion was so slow that it was not noticeable. As they moved they carried along rocks, loose soil,

Brown Brothers.

AN ALASKAN GLACIER
A river of flowing ice.

small stones, and boulders of various sizes, and when they melted in warmer climates they deposited these along their courses. Such glacial deposits may be seen in various sections of the country. As the ice sheets moved over the rocks they rubbed off small particles that today form a part of the soil of the earth. Glacial soils are usually fertile.

Wind.—Wind aids in the formation of soil by striking against walls of rock and causing small parts to break off which gradually disintegrate and become soil. Sometimes the wind picks up gritty stone particles and drives them against the rock masses, wearing

them away. The wind is especially useful in transporting soil from place to place after it has been formed.

Air.—Air contains oxygen which unites with various substances and causes them to break apart by oxidation. When these substances form a part of rocks, the rocks are affected by the air and soon decompose, crumble, and form soil. The reddish soil seen at the base of some mountains is the result of the oxidation of rock that contained iron ore. Even manufactured iron oxidizes, or rusts, so rapidly in moist air that it must be protected by paint or other coatings.

Plants.—Fertile soil must contain a certain amount of organic matter. Part of this, the *humus,* is provided by plants. It results from the decay of plant tissue. Fertile surface soil found in swamps and in wooded areas contains a large percentage of humus. Dead twigs and fallen leaves change to humus. There are certain minute plants in the soil known as soil bacteria that act upon humus and make it a part of the soil.

Animals.—Part of the organic matter in the soil is provided by animals. Some of it results from the decay of dead animal material and some from the excretions of animals spread on the surface of the soil. A large amount, however, comes from material that has passed through the digestive systems of earth worms and has there been ground fine and enriched with organic matter. Charles Darwin estimated that over 50,000 worms may be found in an acre of land, and that it is possible for ten tons of soil to pass through their bodies in a year and thus be brought to the surface in the form of worm casts.

Importance of Life in Soil.—The importance of organic life in the soil cannot be overestimated. Earthworms and other burrowing creatures break up the soil and so provide avenues for the introduction of the air and water needed by plants. Certain bacteria add greatly to the fertility of soil, for they take from the air nitrogen, a substance needed for plant growth, and change it into a soluble form that plants can use.

Kinds of Soil.—Soils are classified according to the kinds of materials they contain. A soil having a large percentage of clay is called a *clay* soil. One having a large percentage of sand

is called a *sandy* soil. One in which there is a combination of clay, sand, and humus is called loam. A loam soil is most desirable since it contains, in better proportions, the materials needed by plants for making food.

Uses of Soil.—The soil is very useful to man for other purposes than for growing plants. This is especially true of soils containing a large proportion of clay or silica, for they are used in making pottery, bricks, and glass.

Pottery.—Many common objects of our everyday life are made from clay. Clay, for example, is the basis of china and porcelain. In ancient times the clay was roughly shaped by hand and sun baked. Today the process is more complicated. The clay must be entirely free from iron or any other substances which would tend to color or stain the finished material. The selected clay is thoroughly dried and then ground to a fine powder. The powder is made pliable by the addition of water. The material is then shaped by hand or by machinery into the forms desired. These are dried and then are subjected to a high temperature, or *firing,* for many hours and permitted to cool very slowly. The resulting plates or vases or other articles are still in a porous state, although hard. They are then treated with a material to close the pores and to give them, after another baking, a glass-like finish, or glazing. If the plain pottery is to be decorated, the design is then placed on the pieces and they are again fired. Certain finer potteries require even additional processes.

Bricks.—From ancient times bricks have been made from clay. The early bricks were generally made by molding the original clay as found in beds and by baking the forms in the sun. In many cases, the bricks did not dry uniformly and consequently they tended to warp and crack. Our modern bricks are made of clay, often with the addition of small amounts of sand, ashes, or marl, which is itself a combination of clay, sand and limestone. Some marls contain sufficient iron to give bricks, when baked, their common red color. Other marls, lacking this material, produce the common light brick.

As in the case of pottery, the clay and other materials are mixed in proper proportions. The resulting mixture is moistened

and worked by machinery until plastic and is then pressed into molds. After these bricks have been slightly dried naturally they are placed in ovens and dried artificially. A better class of brick is formed from clay which is forced by machinery through openings in a big container, coming out as a brick bar which is cut into individual bricks of proper size. These bricks are then dried and baked. Bricks of still finer texture are made by using less moisture in the original mixture and by pressing the material to the shape desired by very powerful machinery. These bricks also are baked and form the high class pressed brick we see today.

Drainage pipes and building tiles, or hollow blocks, are made of brick clay which has been molded to shape and baked. Ornamental tiles are glazed and finished like the better grades of pottery.

Glass.—Ordinary glass is a mixture of sands containing silica, soda ash, and limestone in proportions varying with the kind of glass desired. For window glass and cheap plate glass the proportion is 6, 2 and 1. Since the quality of glass depends in large measure upon proper proportioning and mixing of these ingredients, a machine has been devised to give absolute accuracy of proportion as well as uniform and perfect mixing.

These carefully combined raw materials are placed in large tanks, or furnaces, lined with fire brick. They are heated to a very high temperature by flames of gas until, by melting, they form glass. When at the right consistency, this glass is taken from the furnace and blown, pressed or rolled into shape.

In making glass tubes, like those used in science laboratories, a small amount of melted glass is removed from the furnace on the end of an iron tube, or blow pipe. By blowing through the other end of this tube, the glass blower forms a giant glass ball like a soap bubble. He then clamps one end of the ball on a machine and pulls on the iron tube, drawing the glass into the form of a tube.

To make window glass, the proper amount of the molten mixture is conveyed to a glass blowing machine which blows the glass and then draws it into large cylinders. These are cut length-

wise and are again heated until they soften and flatten into sheets of glass which are slowly cooled. This second heating and slow cooling process is called annealing. It strengthens glass against cracking and breaking.

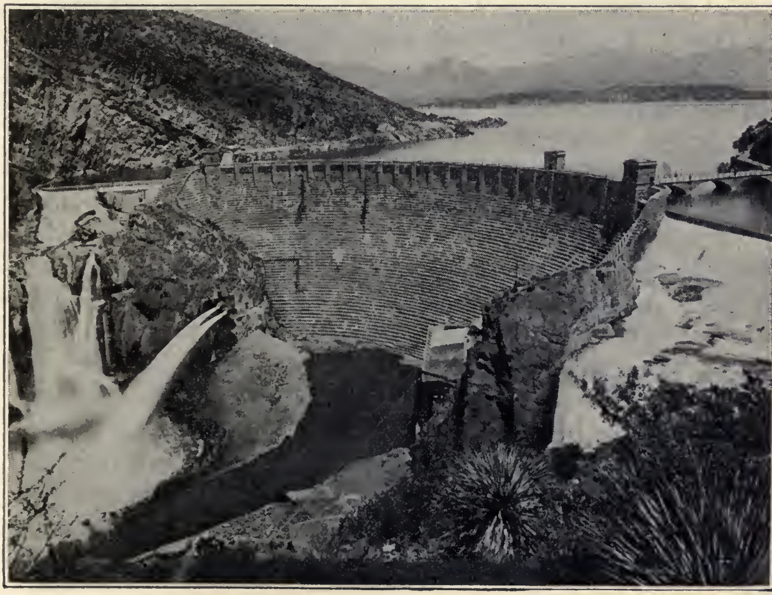
Bottles and small glass objects are made by machines which mold, press or squeeze the molten glass into shape. Plate glass is made by pouring the molten material onto a flat, metal table where it is rolled by machinery to its proper thickness. When cooled, it is rubbed and treated until flat and smooth. The shaping and finishing of glass is made possible because molten glass solidifies slowly.

Glass-making is among the oldest of industries and figures of glassmakers with their blow pipes may be seen on many an ancient monument. It has only been since the beginning of the century that glass has been made by machinery. Within the past thirty years great machines have been invented which take the place of glass-making by hand and which turn out various glass products in enormous quantities daily.

Importance of Knowledge of Soil.—The dependence of all living things on the soil for the production of the food essential to their growth and development makes necessary some knowledge of the nature and composition of soil. *The life of all creatures depends directly or indirectly upon food substances provided by plants.* Plants, in turn, get substances from the soil to aid in the manufacture of their food. If any of the essential substances were for any reason removed from the soil, all life on the earth would perish. This fact makes plain the importance of some knowledge of the soil.

Necessity for Cultivation of Soil.—Unless soil is cultivated, that is, plowed and harrowed, it soon becomes covered with a growth of weeds. Their removal, however, is not the only reason for cultivating soil. Cultivation crumbles the soil into small particles, thus bringing it into the best possible condition for holding moisture until it is absorbed by the root hairs of plants. Besides, it aids the movement of the air in the soil. Air and moisture are both necessary for vigorous plant growth.

Irrigation.—In localities where a natural water supply is lacking, it becomes necessary to rely on irrigation, that is, on an artificial supply of water. In the dry or arid regions of the west, thousands of acres are made capable of production through irrigation. Immense dams are constructed to hold the water. The Roosevelt dam in the valley of Salt river is an illustration. This dam forms a lake twenty-five miles long and two miles wide with a depth in places of 225 feet. It furnishes water for over 200,000



U. S. Bureau of Reclamation.

ROOSEVELT DAM
A great irrigation project in Arizona.

acres in the vicinity of the city of Phoenix, Arizona. It is one of a large number of such dams built in various parts of the west by the United States government.

Dry Farming.—In some semi-arid regions where the crops ordinarily fail owing to insufficient moisture, a kind of cultivation known as dry farming is often employed. This method is based on the fact that moisture does not evaporate rapidly from

soil whose surface is kept broken up by frequent cultivation. In practicing dry farming, a plot of land, though required to produce a crop only every other year, is tilled after each rainfall, in order to keep the soil loose and thus conserve the moisture by retarding evaporation. In this way the soil gathers and holds sufficient moisture during one year to supply and mature a crop during the following year. Of course, this system is used only in regions where there is an insufficient rainfall.

Soil Exhaustion.—Soil remains productive only when it receives constant supplies of the substances taken from it by growing plants. If these plants are left to die and decay, the soil receives back the nutrients, or foods, they took from it in growth and the soil remains rich. But when crops are raised and removed without replacement of these essentials for plant growth, the soil becomes exhausted and can no longer produce a good crop. Such a condition is called *soil exhaustion.* Farms are sometimes abandoned as useless because the soil no longer contains the compounds that render it productive. Other reasons that cause loss of productive power are the washing away, or erosion, of the surface soil by heavy rains, an inadequate supply of water, and a lack of humus in the soil.

Lack of Humus.—The lack of humus is usually the main cause for any decrease in the yield of farm crops, since it leads to the development of other unfavorable conditions in the soil. Without humus, the soil loses its water-holding power more easily, and, when it hardens, prevents the admission of air. Both air and water are necessary to insure the development of plant life.

Keeping the Soil Fertile.—Soil will continue to produce crops in sufficient quantity to reward the farmer for the labor involved in cultivation only when it receives enrichment in return for that which a growing crop removes. This may be brought about by the use of fertilizers and, to some extent, by crop rotation.

Fertilizers.—Fertilizers are substances containing the elements needed by the soil to replace those taken from it by growing crops. In soil where there is sufficient moisture the elements

usually most needed are nitrogen, phosphorus and potassium. The fertilizers used should contain nitrates, phosphates and potash. Farm manure is a good fertilizer when used in sufficient quantity. It contains nitrogen, potash, some phosphoric acid and other ingredients removed from the soil by growing crops. However, it lacks enough phosphoric acid, and should be reinforced with a commercial fertilizer, such as bone meal, acid, or rock phosphate. Wood ashes are sometimes spread on the soil to provide potash.

Rotation of Crops.—By *rotation of crops* is meant the raising of a series of different crops on the same plot of land in different years. It is claimed that this plan aids in the control of weeds, fungi and insects, conserves the fertility of the soil by keeping up the humus supply, prevents infection by germs that are harmful to plant life, and permits the alternation of deep-rooted and shallow-rooted crops. For example, the raising of crops of corn on soil infested with the potato-scab deprives this fungus of its food. Certain crops add nutrients to the soil. Thus leguminous plants, such as clover and peas, are able to take nitrogen from the air and restore it to a soil from which it has been removed by other plants.

SUMMARY

According to their origin, rocks are classified as igneous, sedimentary and metamorphic.

Igneous rocks are rocks which have cooled from a molten mass. Granite is an example.

Sedimentary rocks are formed by material deposited in layers. Sandstone is an example.

Metamorphic rocks are sedimentary rocks whose forms have been changed by heat and extreme pressure. Marble is an example.

The principal rocks used for building stones are granite, marble, sandstone, and limestone.

Cement is a modern building material, made largely from limestone. Concrete is a mixture of cement, sand, and stone.

Most metals are extracted from rock-like masses, called ores, by crushing and heating.

Soil consists of small particles of rock and organic matter supplied by plants and animals.

Water is the chief cause of erosion. Other causes are wind, glaciers, ice, air, animals, and plants.

The principal kinds of soil are clay, sand, and loam. Clay is used for the making of bricks and pottery.

Glass is made from a mixture of sand, soda, and limestone, usually by heating, blowing, rolling, and pressing.

Cultivation of the soil prevents weeds, increases the circulation of air in the soil and adds to the soil's capacity to hold moisture.

Soil exhaustion is caused by the failure to restore to the soil the nutrients which growing plants take from it.

Soil is kept fertile by adding to it materials to replace those taken from it by growing crops. This is accomplished by the use of fertilizers and by proper crop rotation.

The importance of some knowledge of the soil is evident when we recall that the continuance of all kinds of life on the earth depends on the fertility of the soil for food production.

Fact and Thought Questions

1. How are rocks classified as to origin?
2. Describe ways in which sedimentary rocks are formed?
3. What are igneous rocks? Give examples.
4. Complete these statements orally:
   (a) The principal kinds of building rocks are ——.
   (b) —— is a rock used in sculpture.
5. What is cement? How is it made?
6. What is concrete? Name several uses of concrete.
7. What are ores? Outline briefly the process of extracting iron from ore.
8. What is soil? How is it formed?
9. Name the principal kinds of soil.
10. Name four agents that aid in soil formation. Tell how each acts.
11. At the bottom of most stone cliffs are many fragments of stone from the cliff face. What caused them to break off?
12. How are bricks made?
13. Describe in brief the process of making common pottery.
14. Why is soil cultivation necessary?
15. What is meant by soil exhaustion?
16. How can soil be kept fertile?
17. Why is knowledge of the soil important?

18. What facts or principles stated in this chapter apply to the care of a home garden?
19. Why does spreading dry leaves or straw over the soil protect plants during drought?

Projects

1. Make a collection of different types of rocks, labeling each to show its character, its general uses, and the locality from which it came.
2. Make a collection of as many different kinds of soil as you can find in your neighborhood. Label each specimen with its general class, title, and the locality where found.
3. Make a wooden mold and prepare and cast a cement block.
4. Make a brick from materials in your neighborhood and bake it in the home oven.

Outdoor Observation

1. Observe and list all construction uses of (a) stone, (b) cement, (c) metals, noted on your way to and from school.
2. Observe the mixing and placing of cement and concrete, or the erection of iron work on some structure. Record your observations.
3. Observe the different layers of soil or rock which have been exposed by weathering or erosion on a hillside or along a stream. Record your observations.
4. Dig a small hole in your yard to a depth of three feet, removing the earth carefully and noting the changes in the character of the soil and the thickness of the different soil layers. Make a labeled sketch and record your discoveries.

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Common Minerals and Rocks................................ *Crosby*
Soil Fertility and Permanent Agriculture........................ *Hopkins*

GENERAL THOUGHT QUESTIONS FOR DISCUSSION AND REVIEW

GROUP IV

1. Mention one important value of science to you personally. Give at least *one* good reason for your answer.
2. Mention a fire hazard that may exist in (a) the home, (b) the school, (c) some public meeting building. Tell what means should be taken to eliminate each hazard.
3. By aid of labeled drawings or blackboard sketches, tell how you have proved the following statement: Water exerts pressure. State what you did, tell step by step what happened, and give your conclusion.
4. Do metals expand when heated? Give an illustration to prove your answer.
5. Why is it easier to tip over a canoe containing a standing person than one containing a sitting person?
6. Name six common instruments that use the principle of the lever. State the class of lever in each case.
7. Why does an electric bulb filled with gas get hotter than one containing a vacuum?
8. How can a heavy boy and a light girl sit on a see-saw so that it will balance exactly?
9. Is it safe for an ocean-going steamer, loaded to full capacity, to ascend a fresh water stream? Why?
10. Why do we oil machinery?
11. Why does an airplane motor sometimes stop when a very high elevation is reached?
12. Why does the rear of an automobile get more dusty than the front?
13. Show, by labeled drawing or blackboard sketch, how you have demonstrated the action of some device that uses atmospheric pressure. Tell briefly (a) what was done, (b) what happened, (c) your conclusions.
14. Is it true or false that heat dries up water? Why?
15. Complete this statement: Water rises in a coffee percolator because ——.
16. Is it true or false that there is less eyestrain in reading print on glazed paper than on unglazed paper? Why?
17. Why do some clouds look white and others very dark?
18. What causes the sharp crack heard when a bat hits a ball?
19. Show by labeled drawing, on paper or blackboard, how you have demonstrated the circulation of water by convection currents. Tell briefly (a) what was done, (b) what happened and (c) your conclusions.

20. Name common tools or instruments that illustrate the principle of (a) the wheel and axle, (b) the wedge, (c) the pulley.
21. Why is it easier to roll a barrel up a plank into a wagon than to lift it up?
22. How does an overflowing stream help the flooded lowlands? How does it injure them?
23. What elementary machines can you locate in an automobile?
24. Compare steamships and submarines.
25. How does a steam engine differ from a steam turbine?
26. Why isn't a cooling device as necessary on a steam engine as on a gas engine?
27. State advantages of motor transportation lines over steam transportation lines for small lots of freight.
28. Compare a dirigible and a steamship.
29. What might happen if most of the freight load of a steamer were placed on one side? Why?
30. Why are houses with heavy brick or stone walls likely to be cooler in the summer and warmer in winter than ordinary wooden houses?
31. What supplies the energy that runs a clock? How is it applied?
32. Name four ways in which land transportation affects our lives.
33. Is it true or false that grass and shrubs will endure bitter cold better if there is snow? Why?
34. What would you add to a clay soil that bakes readily in the sun to make it more usable for garden purposes?
35. Why is it harder to stop a railway train than an automobile, if both are going at high speed?
36. Is it true or false that automobiles are seldom struck by lightning? Why?
37. Does a locomotive do more work in a fixed time in drawing a train at 30 miles an hour than in drawing it at 40 miles an hour? Explain.
38. If one cylinder of a four cylinder automobile motor fails to fire, how does it affect the power of the motor?
39. Why are copper wires for carrying electric current frequently wrapped with cotton or silk?
40. Why are the slides placed upside down in a projecting lantern?
41. Why does not an electric heater "exhaust the air" as a stove does?
42. Why are bricks baked?
43. Why is new-laid concrete kept sprinkled with water on a very hot day?
44. Name two processes that must occur in the atmosphere before rain can fall. Give one cause of each process named.
45. Is it true or false that hard water requires more soap to make a lather than soft water? Why?

CHAPTER XXII

PROTOPLASM

No living thing—plant, animal or man—is wholly alive. In each and all there is some lifeless matter. Only a part of the matter in a wonderful towering tree, for example, is live matter. But it is that live part which makes the tree grow and take on beauty of form and structure.

Just as matter is composed of molecules, so we may think of the living parts of our bodies as made up of countless millions of cells. It is the growth of these cells and the formation of new ones from them that enable our bodies to increase in size and to repair the wastes of use.

The material of which all these cells are made is called protoplasm. To understand ourselves and all living things around us we must know about this protoplasm.

All living things have certain activities without which they cannot exist. These activities are known as *functions,* or *life processes,* and they are carried on by some organ or organs of the living thing, or organism.

The functions, or life processes, are *sensation, motion, respiration, food-taking, digestion, absorption, circulation, assimilation, excretion and reproduction.* They are not only activities of man but are also activities of all living animals. Plants have similar activities. In addition, plants perform a function not possible for other living things. They not only take food and use it as man and animals do, but green plants actually manufacture food. Without this work of the green leafy plants there would be no food, and all life on the globe would perish.

Man, animals, and plants are also alike in composition. Their living parts consist of *protoplasm.* Protos means first and plasma means form; so protoplasm means the original simple form of substance of which living things are made.

When examined under the compound microscope, protoplasm appears to be a thin, granular, nearly transparent fluid. Although

constantly in process of change, it seems in all essential ways to be similar in all plants, in all animals, and in man.

Protoplasm not only has the same appearance in man, animals, and plants, but it also has the same chemical composition and the same characteristics. It is composed of the elements oxygen, hydrogen, nitrogen, carbon, sulphur, and phosphorus.

A PLANT CELL

A magnified stinging hair of a nettle. Arrows indicate the direction the protoplasm moves.

Among the properties of protoplasm are response to influences outside itself, ability to move, to breathe, to take in, digest, and assimilate food, to excrete waste material, and reproduce itself.

Protoplasm may be observed with the compound microscope in the stinging hairs of the common nettle, in the eggs of the starfish, in the cells of young plant shoots, and in the cells of the leaves of certain water plants.

Protoplasm makes up the living part of all organisms. Nearly every organism contains lifeless as well as living matter. There is no protoplasm in lifeless matter, such as the mineral matter of our bones, the outer layers of our skin, the skeletons of sponges and corals, the feathers, claws, and beaks of birds, the outer covering of insects, and the outer bark of trees.

Huxley called protoplasm the *physical basis of life* and there has been no better definition. That it is the physical basis of life is proved by the fact that life is found only where protoplasm exists.

AN AMŒBA

N. Nucleus.
P. Protoplasm.

Cells.—We all know that bodies are made up of organs. These organs are composed of *tissues,* and tissues are composed of collections of similar *cells.* A cell is a tiny amount of protoplasm which may or may not be enclosed in a membrane. It can be seen only with the aid of the compound microscope, and when thus observed will usually show at or near the center a minute

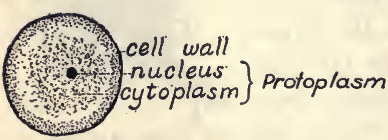
rounded portion that is more dense than the surrounding part. This is called the *nucleus.* Max Schulte, a noted biologist, defined a cell as a mass of protoplasm containing a nucleus.

In order to see the nucleus under the compound microscope the cell should be stained with a suitable dye.

We are accustomed to think of a cell as a walled space, like the cell of the honeycomb. Yet it is not difficult to explain how the word came to have the meaning now assigned to it in science. About the year 1665, Robert Hooke, in studying lifeless cork tissue, discovered that this vegetable substance was composed of myriads of microscopic walled spaces. These contained no living matter and were called cells. Later, when it became clear that while the cork was growing these cavities were filled with living matter, the word cell continued to be used to indicate these units of structure.

The compound microscope shows that living animal tissue is, like the cork, composed of tiny units, or cells. Although they usually lack the clear-cut walls found in plant cells, yet they do not run together. While they present no rigid wall parts, the cell theory assumes that the surface of each cell possesses a film of extreme delicacy yet of sufficient firmness to hold its contents in place. This film, or covering, is called a cell wall or cell membrane. Cells are exceedingly small, many being less than one one-thousandth inch in diameter.

A typical plant or animal cell consists of three primary parts: the *nucleus,* a very small rounded body within the cell substance; the *cytoplasm,* the part of the protoplasm other than the nucleus, and a covering called the *cell wall.* The cytoplasm and the nucleus taken together constitute the protoplasm.



A Typical Cell

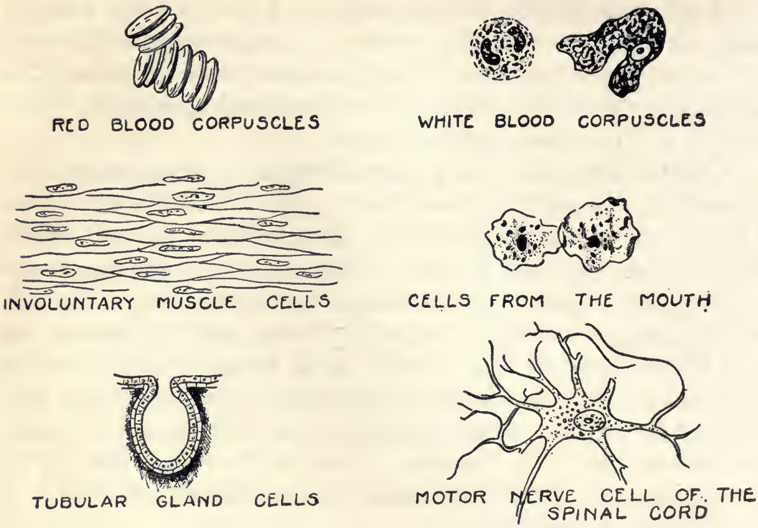
Although the egg of every animal illustrates the structure of a cell, that of the starfish shows it with special clearness and may be taken as typical of all cells. Since the egg of a starfish is not available to many, the egg of a fish, the egg of the seaweed known as fucus, or onion-skin cells may be examined.

A cell may assume various shapes in order to adapt itself to its mode of life, or to the pressure of neighboring cells which in many-celled organisms crowd it, and change its shape to a greater or less extent. Cells may be hexagonal, threadlike, brick-shaped, or of various irregular forms.

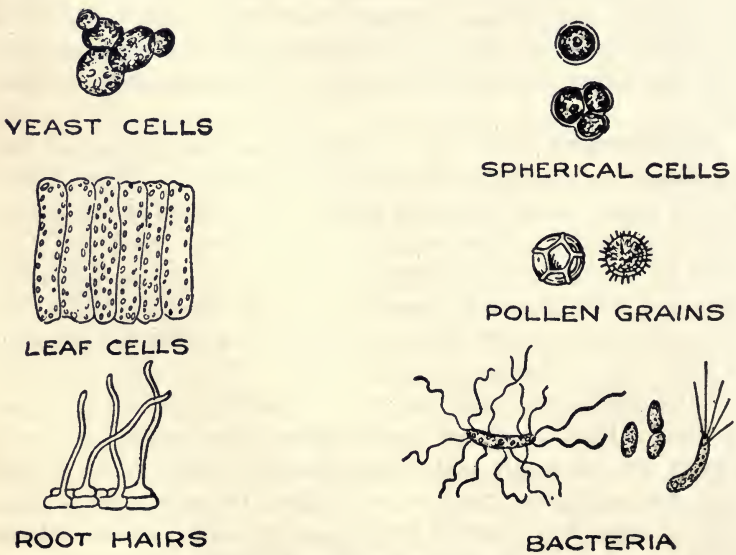
Cellular Structure of Living Things.—A living thing consists either of a single cell or of many cells. The cell which forms a single-celled living thing is wholly independent. In many-celled living things this is not the case. These consist of groups of cells having definite functions to perform that are necessary to the life of other groups of cells. The body of man, which represents the very highest type of life, is made up of groups of cells—muscle cells, nerve cells, bone cells—so connected and interrelated that each group depends on the activity of the other groups to aid in the performance of its function. Thus, by the co-operation of all the groups, the life of the organism is maintained and kept in a normal healthy condition.

Functions, such as breathing and digestion, are performed by organs composed of tissues, made up of cells. This make-up of cells, tissues, and organs is known as *structure*. Since the cell is the smallest part, or unit, of a living thing that can perform functions, it is called the unit of function. It is also the unit of structure.

Environment.—In order to sustain life the presence of certain factors or conditions is absolutely necessary. These factors are *air, water, food, heat,* and *light*. If it were not for air we could not breathe. Even a short time without water and food shows us how necessary are these factors if we are to keep alive. Heat and light, too, are essential to a healthy existence. Not only human beings, but all living things are absolutely dependent on these factors for their very existence. These, with other less essential conditions, make up the surroundings of every organism that exists. As our surroundings are subject to great changes we can easily understand that they can lead to equally great changes in the structure or habits of an animal or a plant. These changes may be either physical or chemical, or both. Hence all life involves a constant succession of changes.



Various Forms of Animal Cells



Various Forms of Plant Cells

SUMMARY

All living things have certain activities, called functions. They are: sensation, motion, respiration, food-taking, digestion, absorption, circulation, assimilation, excretion, and reproduction.

All living matter consists of protoplasm.

Protoplasm when examined under the compound microscope appears to be a thin, nearly transparent fluid. It has the same appearance in all living things.

Protoplasm has the same chemical composition and performs the same functions in all living things. It consists of oxygen, hydrogen, nitrogen, carbon, sulphur, and phosphorus.

Nearly every organism contains lifeless as well as living matter. There is no protoplasm in lifeless matter.

A tiny unit of protoplasm is called a cell. A typical plant or animal cell consists of three essential parts: the nucleus, a denser, rounded portion; the cytoplasm, the substance around the nucleus; and the cell wall. Cells may assume various irregular forms.

A living thing consists either of a single cell or of groups of cells.

Cells make up tissues. Tissues make up organs. Organs are essential parts of every higher living thing. This make-up of cells, tissues, and organs is called structure. The cell is the unit of both structure and function.

Air, food, water, heat, and light are necessary to sustain life in all living things. They make up what is known as environment.

Fact and Thought Questions

1. Describe the appearance of protoplasm.
2. In what forms of plant and animal life can protoplasm be observed?
3. Why does it hurt to pluck a hair from the head but not to cut it?
4. Name some parts of the human body and of birds that contain no protoplasm.
5. Make a drawing of a typical cell, labeling each important part.
6. Define (a) structure, (b) function. Give illustrations of each.
7. Define cell, tissue, organ, organism.
8. Why is a cell called the unit of both structure and function?
9. What is meant by environment?

10. Name the conditions necessary for the growth and development of living things.
11. Why is man less dependent on natural surroundings for food and heat than are animals?
12. Is the lifeless matter in a living body of any real value or is it waste material? Why?

Projects

1. Make a collection of various kinds of tissue. Label each kind.
2. Examine with a microscope, separately, several pollen grains of different flowers. Each is a cell.

Outdoor Observation

Observe, in the course of your walks, trees and other growing things and list or collect parts to show lifeless and live matter.

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General Biology .... *Abbot*

CHAPTER XXIII

ONE-CELLED AND MANY-CELLED ANIMALS

We move in a world populated by invisible live things in great number and variety. Only powerful microscopes can strengthen our sight sufficiently to enable us to discover and study some of them.

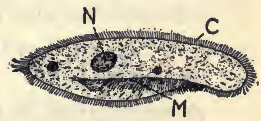
Imagine a creature that moves about without legs, eats without a mouth, and breathes without lungs, and that is so tiny that countless thousands may inhabit a drop of old milk. Small as they are, creatures like this may influence our health for good or ill and may even destroy life itself.

The *protozoan,* or one-celled animal, is the simplest form of life. To know about it helps us to understand more complex forms. The "slipper animal," or paramecium, is the one-celled animal commonly studied. The amœba is another form worth studying.

The Paramecium.—1. Observe a living specimen, by use of a compound microscope, and determine its shape, size, and how it moves.

2. Observe the parts of the cell as far as possible.

3. Using a prepared stained specimen, observe the nucleus, and by use of a chart learn the position of the cilia, by which it moves. Observe the other parts.



A PARAMECIUM
N—Nucleus.
C—Cilia.
M—Mouth.

4. Make an enlarged labeled drawing of the animal, indicating the cell wall, the protoplasm, the nucleus, the cilia, and the food vacuoles, or spaces containing food.

Functions of a Paramecium.—This small, one-celled animal, without special organs, performs all the functions of larger organisms. It is sensitive; it moves; it breathes; it takes, digests, absorbs, circulates and assimilates food; excretes waste matter, and it reproduces.

Sensation.—Although the animal has no nerves, or organs equivalent to nerves, it responds to touch, light, chemicals or

electricity. This shows that it possesses some degree of sensation.

Motion.—That it has the power of motion is readily seen when the animal is looked at under the microscope. Motion is effected by the *cilia,* which are hair-like projections of protoplasm, exceedingly numerous on all parts of its outer surface. Using these cilia like tiny oars, it changes its position with great rapidity.

Respiration.—Oxygen is taken in through the very delicate thin covering of the organism and carbon dioxide, resulting from oxidation of the protoplasm and the food, is thrown off by the same process.

Food-taking.—Bacteria and other minute forms of plant and animal life constitute the food of a paramecium. On one side of the animal there is a funnel-shaped opening, called the *gullet.* Its walls are lined with cilia, by the movement of which the food is taken into the body. There the food is gathered into little balls which appear to be enclosed in a rounded area known as a *vacuole.*

Digestion.—The food is made soluble by digestive juices, or *enzymes,* supposed to be similar to those which serve the same purpose in other animals.

Absorption and Circulation.—The digested food is absorbed as it is circulated within the cell by a movement called *streaming of the protoplasm.*

Assimilation.—As in other animals, there is a constant using up of protoplasm, which must be renewed. This is effected by assimilating the nourishing part of the digested food. Since the animal is constantly reproducing by division, the necessity of assimilation of material to produce new protoplasm, not only to sustain its own life but also the life of its offspring, is apparent.

Excretion.—Excretion of wastes is effected by means of contracting vacuoles in which the wastes collect. These vacuoles appear to burst and thus eliminate the wastes from the cell body.

Reproduction.—Reproduction is effected by *cell-division,* or *fission,* and by *cell-union.* In the first method the animal simply divides into two parts, each part taking one-half of the material essential to life. It has been observed that after a num-

ber of divisions the new animals are of less size than the parent and do not appear to have the same vigor.

While this method is the common method of reproduction, it sometimes happens that two cells join together for a time and appear to be a single individual, after which they separate. This method is called cell-union, or *conjugation.*

After the two cells have separated, each appears to take on a new lease of life, and the animals resulting from future divisions are larger and more active. It is supposed that this increased vigor is the result of the combining of the nucleus material of the two cells that united.

The Amœba.—

1. Using a compound microscope observe a living amœba; also have available a slide containing a stained mounted specimen and suitable charts.

2. Observe the cell body, noting its glassy, jelly-like appearance.

3. Observe the projections that constantly change. These are the so-called false feet, called pseudopods.

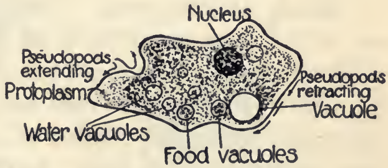
4. Observe the minute particles of food it contains.

5. On the slide observe the nucleus, the denser, more deeply stained part.

6. Make a labeled drawing of the animal, indicating the various parts.

Functions of the Amœba.

The amœba is an animal more simple in structure than the paramecium, but it performs the same functions.



An Amœba

Sensation. — The amœba gives evidence of sensation, although, like the paramecium, it has no sense organs. It responds to the stimuli of light, heat, electricity, chemicals, and contact with particles of sand or food; in other words, it is sensitive.

Motion.—The most characteristic thing about the amœba in its active stage is its ever-changing shape caused by the movements of the *pseudopods,* false feet, as they push ahead in the direction the animal is going.

Respiration.—In respiration the amœba, like the paramecium, simply absorbs air from the water which surrounds it, through its thin cell wall, and in the same way throws off the carbon dioxide resulting from the oxidation of the protoplasm and the food.

Food-taking.—The amœba has no mouth. It secures its food by the action of its false feet which surround the food and enclose it in the protoplasm.

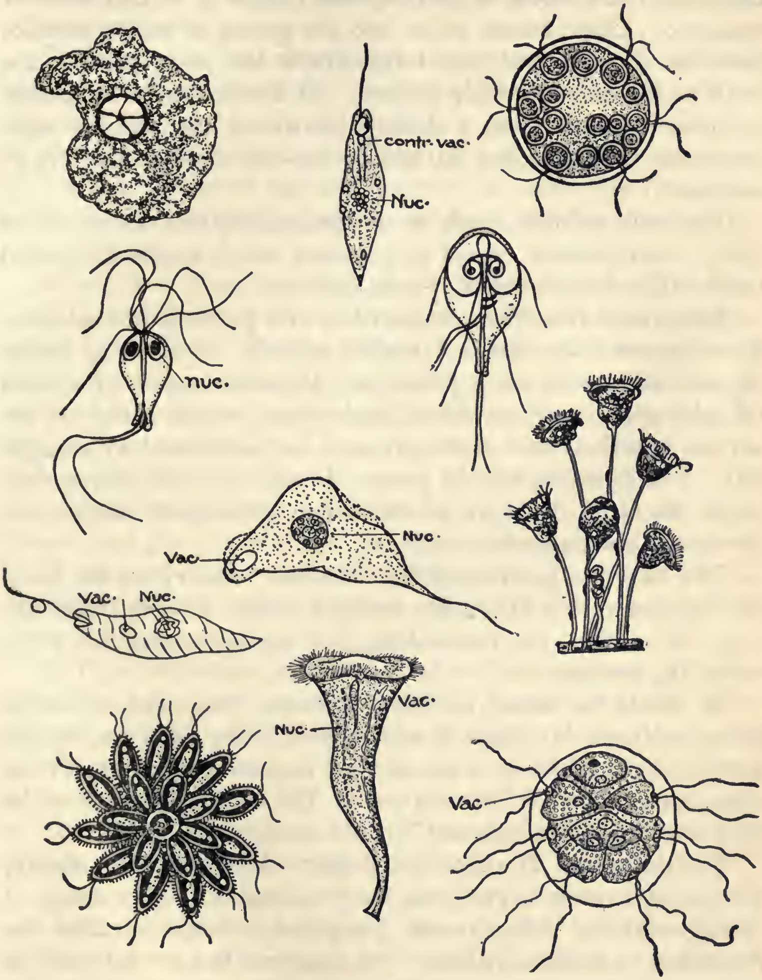
Digestion, Absorption, Assimilation and Excretion.—Enzymes secreted by the protoplasm render the food soluble as it circulates in the cell body. The nourishing elements of the food are rapidly absorbed and assimilated by the animal, and the wastes resulting from oxidation are excreted by means of vacuoles, as in the paramecium.

Reproduction.—Like the paramecium, the amœba reproduces by cell-division, or by cell-union. The fact that it multiplies rapidly when kept under suitable conditions seems to indicate that it undergoes division frequently.

When conditions for life are unfavorable, the amœba sometimes surrounds itself with a membranous wall and apparently becomes lifeless, like an insect in the cocoon stage. On the return of favorable conditions, however, it resumes its life functions.

Kinds of Protozoa.—There are many kinds of *protozoa,* or one-celled animals. Nearly all live in water or in the bodies of other animals. Some protozoa are useful, others are harmful.

Useful Protozoa.—Vast numbers of protozoa exist in bodies of water, and are useful as a source of food for fish. Fish in turn supply food for man. Again, the shell-bearing varieties produce beds of limestone rock. When they die, their shells settle to the bottom of the ocean and form masses of a grayish substance. This has been found in dredgings and is composed largely of the shells of protozoa. Chalk is made up of the shells of these animals. The presence of large deposits of chalk on land is evidence that the region was once the bed of the ocean. Many protozoa are of some importance as scavengers, since they eat particles of dead organic matter.



VARIOUS TYPES OF PROTOZOA

Harmful Protozoa.—Some forms of protozoa cause disease in man. Among these is the *malarial parasite,* which is introduced into the blood of man by the bite of a certain kind of mosquito. Other forms, taken into the system in water, produce intestinal trouble, and one form affects the jaws, causing the teeth to loosen from their sockets. In South Africa thousands of natives perish from a disease known as the sleeping sickness, caused by protozoa introduced into the blood by the bite of an insect.

Domestic animals, such as horses, cattle, and sheep, often suffer from diseases caused by protozoa which secure a foothold in their blood by the bites of ticks and flies.

Metazoa.—In striking comparison with protozoa are *metazoa.* Meta means after and zoa means animals, so metazoa means animals that come after protozoa. Metazoa consist of groups of cells organized into tissues and organs which carry on the various functions that in the protozoa are performed by a single cell. For example, certain groups of cells carry on absorption, while others do the work of excretion. All higher animals are metazoa. Man is a metazoan.

The bird is a good example. In order to carry on the functions necessary for life, it has separate groups of cells for sensation, for motion, for food-taking, for digestion, and for every other life process.

It should be borne in mind, however, that each cell of a group performs in a limited way each of these functions, but its individuality and its work are merged into the general life of the organism of which it forms a part. The cell is thus seen to be the unit of both structure and function in higher animals.

Physiological Division of Labor.—Intestinal cells absorb, liver cells secrete, nerve cells carry sensation. This doing of special work by different cell groups of a body is called the *physiological division of labor.* In a single-celled animal, such as an amœba, there is no such division. Although such an animal has no mouth, it secures food; no lungs, yet it breathes; no stomach and intestines, yet it digests its food. In short, it has no organs, yet it performs all the essential life processes.

In the bird and in all higher animals this is not so. Organs are not lacking to aid in carrying on the life processes. They are necessary in all many-celled animals in order to carry on these processes effectively.

The amœba secures air through any part of its body; the bird requires special organs, called *lungs,* for this purpose. The amœba may take in food through any part of its body; the bird must use its mouth. The amœba may use any part of its body for locomotion; the bird requires legs and wings to aid in moving from place to place. The amœba is simple in structure while the bird is complex in structure.

As we pass from the lower to the higher forms of life there is an increasing complexity of structure, and this is always accompanied by a greater division of labor. That is, when organs are found in an animal, each organ performs a separate function, or seems to be set apart to do a special kind of work. Perhaps the idea may be made clearer by comparison with a factory where each person does the kind of work he is best fitted to do and thus aids in the making of the finished product. So in all higher animals and plants there is a division of labor among the organs which compose them, some organs being fitted or adapted for one kind of work and others fitted or adapted for another kind of work.

Unit of Structure and Function.—Although both the paramecium and the amœba are single-celled animals it should be noted that the amœba is the more simple in structure, since it has no definite part through which food is taken. Each performs all the functions necessary to life, and either may be used to illustrate the fact that the cell is the unit of structure and of function in animals of more complex organization.

More complex animals are composed of organs. The organs are made up of tissues, and each tissue in turn is made up of a collection of cells of the same structure and function. The study of a protozoan shows how a single cell carries on all the vital activities of life. A tissue, for example a muscle, is complex in structure and simple in function, while a cell, an amœba for example, is simple in structure and complex in function.

It seems clear, then, that the simplest forms of animals require no organs of nutrition, since the cells that compose their bodies come into immediate contact with food and with water, containing oxygen, so that all substances needed for growth and for energy-making are taken up readily by absorption. More complex forms, however, since they are made up of tissues containing many cells, must have channels of communication through which to convey food and oxygen to all cells in their bodies. These channels are provided by organs.

SUMMARY

Protozoa are single-celled animals. Metazoa are composed of many cells. All higher animals and man are metazoa.

Protozoa, without special organs, perform all the fundamental life processes of higher animals.

Some protozoa are useful. Other protozoa are harmful, causing disease in man and animals.

In all metazoa there are special cells, or groups of cells, for different functions. This is called the physiological division of labor.

The cell is the unit of both structure and function in all metazoa. All tissues are composed of cells, each of which performs the same vital functions as the one-celled animal.

Higher animals require special organs to aid in carrying on the necessary functions. By means of these organs, all the cells of the body receive food and air and get rid of wastes.

Fact and Thought Questions

1. Define (a) protozoa; (b) metazoa.
2. How does the paramecium secure food?
3. How does the amœba secure food?
4. Mention the life processes of protozoa.
5. Of what economic importance are protozoa?
6. How does the amœba carry on respiration, motion and reproduction?
7. Compare the cat and the amœba for certain common functions of life.
8. In what parts of the kitchen are dangerous protozoa most likely to exist?
9. Why screen windows in summer?
10. Name several common metazoa.

Projects

1. Describe the structure of a protozoan you have observed with the aid of the compound microscope.
2. Make a report in regard to the usefulness or harmfulness of several protozoa about which you have read.

Outdoor Observation

Make a list under proper headings of metazoa observed on the way to school.

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CHAPTER XXIV

OUR BODIES

Among the greatest discoveries of this age of science are those which have to do with keeping well. Our health, our happiness and our success in life depend in large measure on our ability to keep our wonderful bodies in good running order. The work that we do for ourselves, or the service we render others, must be done by our muscles and brain, or by machines and forces they direct.

Our bodies are the most intricate machines in existence. They consist of millions of parts, grouped in a few large systems, each having its particular work to do. A portion of that work is to help and co-operate with the other systems. If one system gets out of order, it is certain to upset others.

Our bodies must be given the right food. They must be safeguarded from dangerous matter and from injuries, and protected from weather. They must be used in the right way to produce efficient results. So well has science been helping us to do these things that today our bodily machines, on the average, are lasting many more years than those of former generations.

In order to know how to use and safeguard our bodies, it is highly important to know what has been discovered regarding their structure and methods of performing their work.

Sensation and motion enable people to adjust themselves to the outside world. Sensation is the means of learning about our surroundings through our five senses. Motion is the means we have of changing our position.

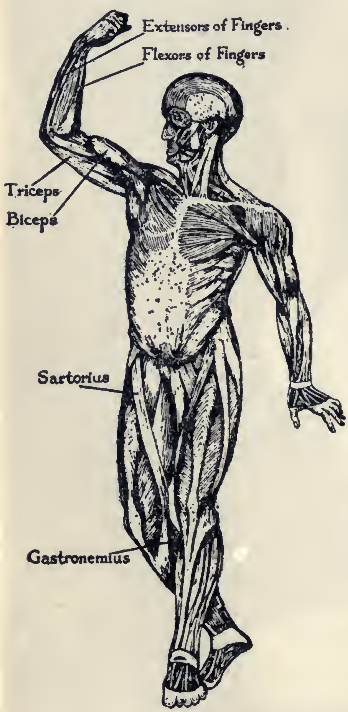
The functions of nutrition include *respiration, food-taking, digestion, absorption, circulation, assimilation* and *excretion.* There is also the function of *reproduction.*

The human body is similar to a lifeless engine in several respects. Both require fuel, or food, and air in order to do work;

Greek Ideal of Physical Development

both have special parts capable of transforming energy into various kinds of work; both may be rendered useless by overwork or accident and both must get rid of wastes. On the other hand, the human body differs from an engine in some respects. It has the power of self-repair, is conscious of various sensations, and is capable of transforming food into energy without help. The human body, to be fully efficient, must have proper food and water, good air, necessary clothing, shelter, exercise, rest, and sleep. The lack of any of these is a handicap.

Functions of Relation—Sensation and Motion.—Individuals relate themselves to the outside world by means of the organs of sense and of motion. All knowledge reaches the brain through the agency of the five senses: *sight, hearing, touch, taste* and *smell.*



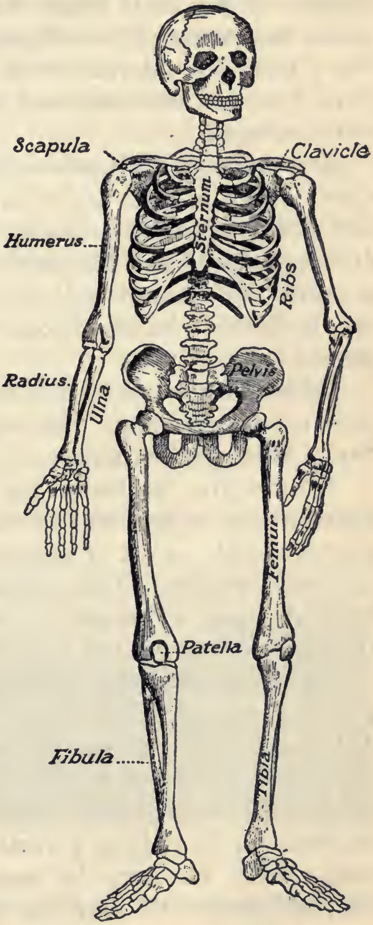
SURFACE MUSCLES

Muscles.—The organs of motion are the *muscles.* In order to appreciate their use we should give a brief consideration to the general structure of the body. The knowledge of this structure should be learned from the observation of our own bodies, supplemented by the use of a skeleton, or of charts showing the most important parts: the head, neck and trunk, the backbone or spinal column, the ribs, the sternum, the pelvis, the pectoral girdle, or bony arch supporting the arms, the bones of the arm and of the leg, and the shoulder and elbow joints. There are more than two hundred bones in the body. The movements of the bones and of all parts of the body are controlled by muscles, of which there are over five hundred.

The greater part of the body outside of the framework, or skeleton, is composed of the flesh, or muscles. Muscles are of two kinds, *voluntary* and *involuntary.* Movements that are under the guidance of the will, such as the movements of the arm or the leg, are controlled by voluntary muscles. Movements that are not under the guidance of the will, such as the beating of the heart or the action of the stomach in digestion, are caused by involuntary muscles.

Muscles are also distinguished as *flexor and extensor*. Any muscle that bends a limb is a flexor muscle and any muscle that extends or straightens a limb is an extensor muscle.

We are not expected to learn the names of all the muscles of the body, but we should know those of a few important ones. The *biceps* muscle that flexes or bends the forearm, and the *triceps* muscle that extends it, are examples of voluntary muscles with which every one should be familiar. All muscles connected with the bones are voluntary. The *heart* is the best example of an involuntary muscle. The muscles of the blood vessels, of the intestines, and of certain glands are other examples of involuntary muscles.



THE SKELETON
The framework of the human body.

It should be noted that, although voluntary and involuntary muscles differ from each other in size and in structure, the voluntary muscles may act involuntarily, as in the case of movements made quickly on the sudden appearance of danger. The muscles of the chest which help in respiration are apparently under the control of the will, and it is possible to stop breathing for a time, but this cannot be continued long. The voluntary control is soon overcome and the breathing process is involuntarily resumed.

Structure of a Muscle.—Examination of a voluntary muscle shows that it is composed of layers and bundles of small fibers. The white network is *connective tissue.* The fibers are made up of still smaller, thread-like parts of cellular structure. These parts are often two inches long, but so small that they can be observed only by the aid of a microscope. Under the microscope the fibers show a cross-striping.

Involuntary muscles are called plain muscle fibers, since they show no cross-striping. The heart muscle, however, is an exception. Although involuntary, its fibers are striped.

Muscles are, for the greater part, arranged in pairs, so that when motion is produced in one direction by one set, there is another muscle, or set of muscles, which brings the limb back to its former position. They are united to bones by *tendons,* tough cords of tissue, and require a constant supply of food and fresh air, regular exercise, and periods of rest.

Effect of Exercise.—Exercise has great influence on the growth and condition of the muscles. We know from experience that muscles develop and become strong by use, and that they soften and become flabby and weak by disuse. Moreover, the right kind of exercise not only builds up the muscles themselves but reacts on the body as a whole. It causes the blood to circulate more rapidly, increases the supply of food and oxygen for the cells, and hastens the excretion of waste material. Furthermore, exercise aids in keeping the temperature of the body normal, and promotes the activity of the digestive system.

The immediate effect of exercise, however, is upon the muscles themselves. By use, they become large, firm, and capable of

accomplishing much labor. Violent exercise should be avoided since it may injure the organs of the body. Exercise should be taken at regular hours daily if the best results are to be had. Spasmodic efforts to increase muscular power usually fail of their purpose. It should be borne in mind that strength is of gradual growth which can be gained only by systematic, well-regulated exercise.

Kinds of Exercise.—Among the most common kinds of exercise are walking, running, jumping, swimming, rowing, riding, and games. The kind of exercise to be chosen depends, of course, on the strength and taste of the individual and the time he can give to it.

Walking is a form of exercise always available for people in health, and love for it should be cultivated by the middle-aged and the old as well as by the young. In England, walking is much more popular than in this country. In order to produce any hygienic result, however, walking must be brisk, and must be continued long enough to produce the physical and chemical changes in the tissues that come with vigorous muscular exercise. Mere strolls are not sufficient. Tramping and mountain climbing are effective.

Running requires more violent effort than walking and should not be indulged in to the point of exhaustion. This kind of exercise is especially fitting for young people, provided it is not carried on for so long a time as to overwork the heart. Many athletic games and sports involve more or less running and they are usually entered into with great enthusiasm and with favorable results to health, except in cases where the spirit of rivalry leads to extreme tests of endurance.

A Close Half-mile!

Running demands the expenditure of a large amount of vital force. Physically it is a very expensive means of movement. Speed cannot be acquired without the contraction of the muscles

of the trunk and neck. This is necessary to hold the head and body in an erect position. Contraction of these muscles affects the process of respiration unfavorably, which in turn interferes with the normal heart action and causes the breathlessness often troublesome to runners. Although running will develop lung, heart, and leg power better than any other form of exercise, there is always present the possibility of serious injury, especially in contests that demand continuous effort for any length of time.

Brown Brothers.

REGULAR EXERCISE BUILDS HEALTHY BODIES

Swimming is a valuable form of exercise, as it calls into action all the muscles of the body, teaches self-reliance, and promotes courage. It also has a practical use because the ability to swim often means the saving of persons from drowning. Swimming, of course, is not the only kind of exercise that calls all the muscles of the body into action. Football, golf, baseball, skating, tennis, horseback riding, and military drill do the same. Exercises like rowing, paddling, bowling, and shooting are espe-

cially valuable in developing the muscles of the upper part of the body, while bicycle riding, dancing, and walking have more effect on the muscles of the lower part.

Physical Culture.—Physical culture is a term used by some to mean systematic exercise of the muscular system, or some of its parts, for the correction of physical defects, for the preservation of health, and for the acquirement of right motor habits. This meaning makes physical results the chief or sole purpose. By others the term is used in a broader sense and, according to their point of view, includes not only the physical results of these activities but also their influence for good on the mind and the character as well as on the body.

With this broader interpretation it will be seen at once that the purpose of physical culture involves more than the athletic ideal and more than the hygienic ideal. Interpreted according to this definition, it involves the education of the whole man, morally and mentally as well as physically. Properly carried on, it means that all shall benefit by physical culture, and not that a few shall be prepared to engage in contests of a spectacular nature, where rivalry and the desire for victory often lead men to overtax their powers, and sometimes to win by means not altogether honorable.

Effect of Alcoholic Drink on Muscular Tissue.—Muscular tissue forms over forty per cent of the weight of an average man. Muscles derive their energy from the chemical union of oxygen and food which are carried to them by the circulation of the blood in their tissues. The efficiency of the muscles in doing their work depends upon the amount of energy stored in the tissues, and upon the nerves which carry to them the impulses to act. The nerves and the muscles work together. How are they affected by the use of alcoholic drink? Doctor Parkes of the British army made an interesting experiment bearing on this topic.

Two groups of soldiers living under the same conditions and having the same kind of food were assigned work of a like nature. One group was allowed a full ration of beer. The other group was allowed no alcoholic drink. After a few days it was found

that the group which had no alcoholic drink accomplished from eighteen to twenty per cent more work than the other group.

In order to make the experiment more conclusive, Doctor Parkes allowed the second group to have the beer, while the first group worked without it. Again the group which had no alcohol did more work.

Experiments were made in regard to the effect of alcohol on the muscular activity of dogs. Four dogs, as nearly alike as possible in age and size, were selected for the experiments. To measure their daily activity a kind of pedometer, an instrument for measuring distance traveled, was fixed in each dog's collar and was read at regular intervals. Alcohol was given to two of the dogs in their food. The other dogs were not fed alcohol and so served as a check, or control. It was noted again and again that the normal dogs were playing actively while the dogs that had had the alcoholic diet were quiet.

In order to test the comparative ability of the dogs as to strength, endurance, and resistance to fatigue, they were taught to return a ball when it was thrown. When a test was to be made, they were all taken to the university gymnasium and a rubber ball was thrown across the room, a distance of one hundred feet, as often as it could be returned.

A record was kept of all the dogs that started for the ball and of the ones that brought it back. One hundred throws constituted a test and the throwing took about fifty minutes.

The first series of tests consisted of 1,400 throws, 100 on each of fourteen successive days. The two dogs that had taken no alcohol in their food returned the ball 922 times, the alcoholics, 478 times. This result shows an efficiency of only 51.9 per cent in the alcoholic as compared with the non-alcoholic dogs.

It is a well-known fact that trainers of men for athletic contests insist that they shall abstain totally from the use of all alcoholic drink during the period of their training. It is said that the men who never taste alcoholic drink of any kind are permanently in a better muscular state, and do not need to go into such strict training for contests, as those who have been in the habit of using it. The testimony of military experts is that soldiers who

never use alcoholic drinks show the greater power of endurance. It would seem, then, that alcohol, even in small doses, diminishes both the quantity and quality of muscular work.

Experiments made by experts in regard to the effect of alcohol on the single cell have shown that it is injurious. Bearing in mind that all muscles are composed of minute cells, and that the effect of the continued use of alcoholic drink, even in moderate amount, is cumulative, there can be no other logical conclusion than that alcoholic drink is detrimental to the work of muscular tissue.

SUMMARY

The functions of the human body and of all living organisms are sensation, motion, respiration, food-taking, digestion, absorption, circulation, assimilation, excretion and reproduction.

Individuals relate themselves to the outside world by means of the organs of sense and of motion. The organs of motion are the muscles. The movements of the bones and of all the parts of the body are controlled by muscles, of which there are over five hundred in the body.

Muscles are classed as voluntary or involuntary, according as they are or are not controlled by the will. They are also classed as flexor and extensor according to whether they bend or straighten a limb. Most muscles are arranged in pairs and are joined to the bones by tendons.

As muscles work and need constant repair, they require a constant supply of food and air, regular exercise, and rest to keep them in good working condition.

Physical culture is systematic exercise of the muscular system.

Experiments have shown that the effect of alcoholic drink on muscular tissue and muscular activity is to reduce efficiency.

Fact and Thought Questions

1. Name the important parts of the general structure of the body and state what organs control them.
2. How do individuals relate themselves to the outside world?
3. How is your body different in function from an engine?
4. Describe the structure of a voluntary muscle.

5. What sports do you take part in? How does each benefit you?
6. In what ways outside of sport have you exercised today?
7. Why is running upstairs harder work than running on a level path?
8. Is deep breathing an exercise?
9. Discuss the merits of different forms of exercise.
10. Why is it less wearisome to walk "up hill and down dale" than for a long distance on a level?
11. State the effect of alcoholic drink on the muscles of the body.

Projects

1. Discover and describe structural adaptations in your body.
2. Describe your favorite recreational forms of exercise.

Outdoor Observation

On the way to and from school, observe people engaged in different occupations, sports, or other activities. Note which activities seem to exercise the body generally; which exercise particularly certain groups of muscles; which make seemingly heavy demands on a few muscles; and which might be said to give severe exercise. Record your findings.

References

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CHAPTER XXV

RESPIRATION

Most of us know how the fires in our stoves and heaters are affected by the amount of air that draws through the fuel. Close the air draft and the fire smoulders or dies; open it and flame and heat increase. So necessary is the oxygen of the air that in great boiler rooms of ships and factories where much power is required, air is forced through the fires under pressure to bring about better combustion.

So, in our wonderful complicated body machines, air is necessary that the food fuel may generate enough heat to warm us and enough energy for our other needs. This air supply is so vital that we cannot stop it for any length of time without serious danger.

Our respiratory apparatus works like an automatic machine to supply air and to remove waste gases. But it should be used in the right way and the air supply should be fresh. If we understand the workings of our respiratory system we will know better how to safeguard it to protect and strengthen our health.

Respiration is the life process, or function, by which energy is made available to the body. It includes *breathing* and *oxidation.*

In man, breathing is the process by which air is taken into the lungs and carbon dioxide is exhaled from them.

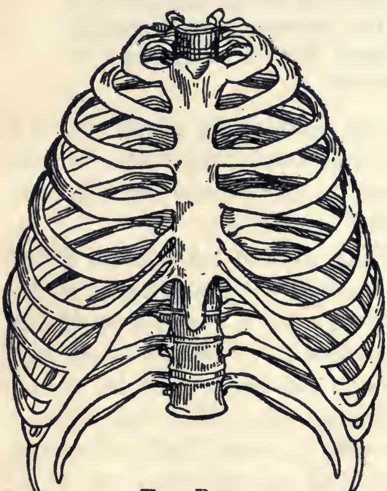
Oxidation is the process by which oxygen, taken from the air in the lungs, is combined with digested food substances in the cells of the body, thus releasing energy for the body's needs. In this process the circulation of the blood plays an important part.

The blood, in circulating through the lungs, absorbs oxygen from the air, and in circulating through the walls of the stomach and other digestive organs it absorbs digested food substances. By means of capillaries, a network of minute tubes, the blood carries both the oxygen and the food substances to all cells in the body. Oxidation, or burning, of food substances goes on in every cell. The wastes from this burning are gathered up and

carried off by the blood, the liquids being carried to the kidneys to be excreted, and the carbon dioxide to the lungs where it is exhaled.

The oxidation of digested food substances in the cells may be compared to the burning, or oxidation, of wood in a stove. The oxygen, coming into the stove in the draft of air, unites chemically with the carbon and the hydrogen in the wood, producing heat energy, carbon dioxide, and a little water vapor. Both the wood and the oxygen change their forms. Part of the oxygen unites with the carbon, forming carbon dioxide, and part unites with the hydrogen, forming water vapor. The carbon dioxide and the water vapor pass up the chimney with the smoke, and a mineral part of the wood, called *ashes,* remains. During this process heat is set free. Thus oxidation does not actually destroy the material burned but causes it to assume different forms.

In the body, the draft is represented by the air taken into the lungs. From this air, the oxygen necessary for burning is absorbed. The fuel is represented by digested food substances absorbed and distributed by the blood to all cells. In body oxidation, there is no flame, but energy is given off. This energy supplies heat, as does the fire, and it makes possible our motion and other activities. The ashes of the fire are represented by the waste products of oxidation in the body which are carried off by the blood. As in the fire, then, fuel and oxygen are necessary to combustion, and combustion results in changes in matter.



THE RIBS

The Respiratory System. The most important organs of respiration are the *diaphragm,* the *ribs,* the *lungs,* the *red corpuscles* of the blood, and the *cells* of the body. These, together

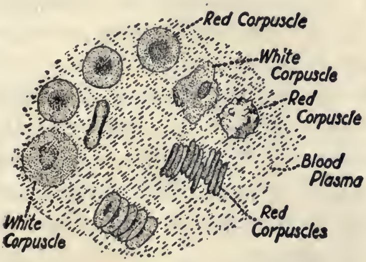
with the *nose, pharynx, larynx, trachea,* and *bronchial tubes,* or *bronchi,* make up the respiratory system of man.

The Diaphragm and the Ribs.—The diaphragm is a dome-shaped muscle attached to the ribs. It forms the floor of the chest. When the diaphragm contracts it flattens and thus deepens the chest. At the same time the muscles connected with the ribs contract, pulling them outward and upward, thus broadening the chest. The air then rushes into the lungs. This action is called *inspiration.* The return of the muscles to their former position lessens the capacity of the chest, and forces the air from the lungs. This is called *expiration.*

TUBES AND AIR SACS OF THE LUNGS

The Lungs.—The lungs are two sponge-like organs composed of minute air tubes, air sacs, and capillaries. They are located in the chest and are protected by the ribs and the breast bone. Each lung is covered with a membrane called the *pleura,* which also lines the chest cavity.

Red Corpuscles.—The blood is composed of red and of white *corpuscles* floating in a liquid called plasma. The red corpuscles are exceedingly small cells consisting largely of a substance called *hemoglobin.* This substance is the important part of these corpuscles because it contains iron which has a strong attraction for oxygen with which it unites readily. When the blood circulates through the lungs, the red corpuscles take up oxygen from the air in the lungs and rapidly convey it to the cells in all parts of the body. The

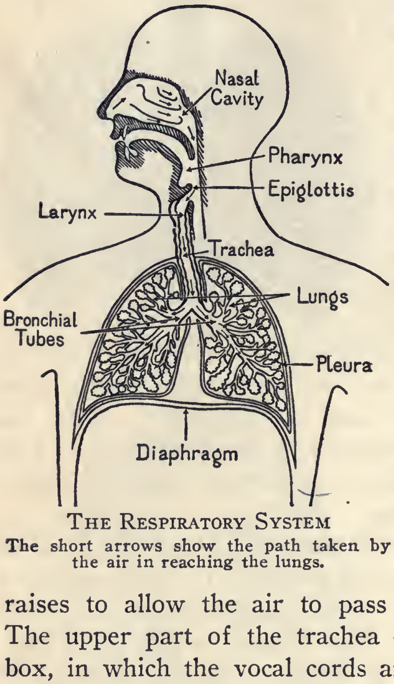


BLOOD CORPUSCLES

distribution of oxygen to all parts of the body is one of the most important functions of the blood.

Nose and Other Organs.—The nose, pharynx, larynx, trachea, and bronchial tubes, or bronchi, form a continuous passage through which the air passes to the air sacs of the lungs.

The nose has two openings, called nostrils, and is lined with *mucous membrane* containing blood vessels. The air is warmed as it comes in contact with this membrane. The nose also contains cilia, or tiny hairs, which, aided by the winding course of the air passage, prevent the entrance of dust and germs into the lungs. By its structure, the nose is thus adapted to do its work well, protecting the lungs from the entrance of cold air, germs and dust.



THE RESPIRATORY SYSTEM
The short arrows show the path taken by the air in reaching the lungs.

The air moves from the nose into the pharynx, or throat cavity; then it passes through an opening covered by a small organ, the *epiglottis,* which raises to allow the air to pass into the trachea, or windpipe. The upper part of the trachea constitutes the larynx, or voice box, in which the vocal cords are located.

The trachea is a small tube about four inches in length, composed of rings of cartilage held together by connective tissue, and lined with mucous membrane. It, like the nose, contains cilia which protect the lungs from dust. The bronchi are two divisions of the trachea which in turn divide and subdivide, ending in the minute air sacs in the lungs.

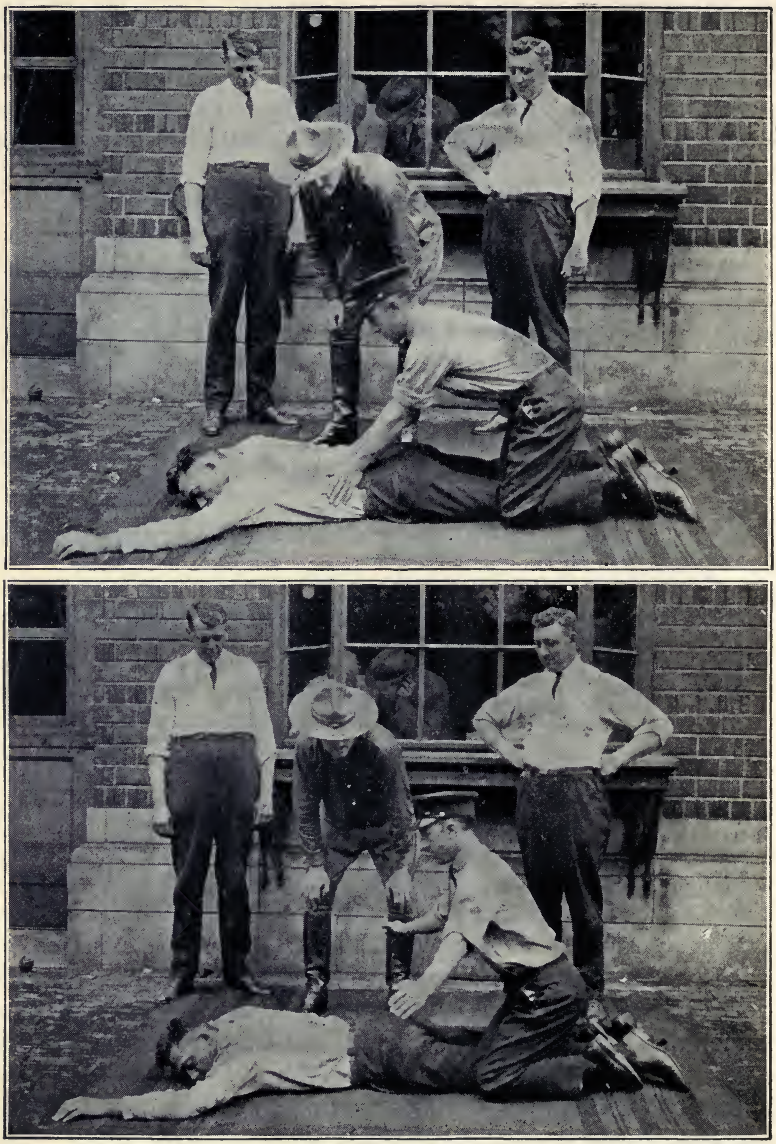
Adaptation of the Lungs.—The lungs are flexible. The air sacs of the lungs have very thin membrane coverings filled with capillaries, thus enabling the oxygen to diffuse readily and to reach

the blood easily as it goes through the lungs. As the blood circulates through the body it carries the oxygen to all the cells. Each cell absorbs as much oxygen as it needs, and throws off its carbon dioxide into the blood current through the thin membrane of the cell walls. This waste is carried by the blood to the lungs where it is exhaled.

Suffocation and Gas Poisoning.—Even a short interruption of breathing shows how important breathing is. Discomfort is at once apparent, and if breathing is not resumed unconsciousness quickly follows. Inability to breathe is called *suffocation.* A person so affected is unable to get air into his lungs to supply oxygen and remove carbon dioxide. If no relief is given, death soon results. The most common causes of suffocation are electric shock, which paralyzes the nerves controlling the muscles used in breathing; drowning; and breathing a gas that will not support oxidation. Gas poisoning is caused by taking into the lungs a gas, such as carbon monoxide, that destroys or paralyzes some of the body cells.

Artificial Respiration *(Schaefer Method)*.—Artificial respiration should be used in cases of gas poisoning and in cases of suffocation where breathing has stopped. Every second counts. Lay the patient face down with his head turned to one side. One of his arms should be extended over his head and the other one so bent that his mouth and nose rest upon the back of his hand. This prevents dust and dirt from being drawn in when breathing starts.

Now, kneel astride one of the patient's legs, facing his head. Placing your hands on both sides of the patient's body just below the shoulder blades, with the thumbs parallel and pointing to the patient's head and the fingers pointing to the ground, scrape the hands back along the body until they strike the hips. Keeping your arms stiff, bear forward and down with your full weight for three seconds. This empties the lungs. Now snap your hands away and allow the lungs to fill for two seconds. Apply pressure again in the same way for three seconds, and remove for two. This should be continued with the same timing and the same rhythm until the natural breathing of the victim is



Amer. Red Cross.

THE SCHAEFER METHOD OF ARTIFICIAL RESPIRATION
The best method of reviving a suffocated person.

restored. Do not give up too easily. Often apparently dead people have been revived after two or three hours of artificial respiration.

As soon as helpers arrive put them to work, instructing them to get a doctor, to secure hot water bottles or hot bricks, and to see that the victim's mouth is kept clear. Tight clothing around the neck and waist should be loosened and the circulation increased by placing the hot water bottles or warm bricks next to the patient's body. These acts are helpful, but should not be allowed to interfere with the rhythm of the artificial respiration.

When the victim has resumed breathing and can swallow, he should be given a teaspoonful of aromatic spirits of ammonia in a half glass of water, or a cup of strong tea, or black coffee, or hot water. This should be fed him in small doses so that he will not choke. If the patient starts to vomit he should be turned on his side so that his throat and mouth do not become clogged. As soon as possible he should be taken home or to a hospital and made to rest. He should have immediate medical attention, as heart collapse or pneumonia often follows cases of suffocation.

Everyone should know how to perform artificial respiration, for the need may arise at any time and knowledge of the process may save a life. There is no better method of treating suffocation than the Schaefer method described above. It is simple as well as effective and can be learned in a few minutes.

The Effect of Tobacco on Respiration.—The fumes of tobacco smoke are irritating to the throat, making it more or less liable to inflammation, and often causing a cough. If inhaled into the lungs, as in cigarette smoking, the air sacs are exposed to the irritating effect of the smoke, and nicotine, a deadly poison found in tobacco, may be absorbed into the system in a vaporized state.

Experiment to Show Effect of Tobacco on Cell Life.—Place a drop of water containing a paramecium on the slide of a compound microscope. Observe the actions of the paramecium. Add to the water a drop of a solution of tobacco obtained by soaking tobacco in a glass of water. What happens to the paramecium?

What do you conclude is the effect of the nicotine poison in the tobacco on cells?

Effect of Alcohol on the Lungs.—It is claimed that the continued use of alcohol causes the capillaries of the lungs to dilate, or grow larger, causing congestion, or an overloading with blood. Doctor Rau of Liverpool, England, reporting his experience with 1,047 cases of pneumonia, including 246 deaths, declares that alcoholism, or continued use of alcohol, tends to make one especially liable to this disease and greatly lessens the chance of recovery when attacked by it. The high death rate from consumption that occurs in places where alcohol is freely used would seem to indicate that this stimulant affects the lungs unfavorably.

Healthy Respiration.—Healthy respiration depends on the free access of oxygen to all the cells of the body. If, through carelessness or bad habits or disease, the organs of respiration become weakened or injured, they are not able to supply the cells with an adequate quantity of oxygen to unite with the food substances. Even though enough food substances are furnished the cells by the blood, the necessary amount of energy for carrying on the life processes of the body cannot be generated without sufficient oxygen, and ill-health will result.

In the first place, whether at work or at play, we should be sure that fresh air is always available. If outdoors, this is an easy matter. If indoors, care should always be taken that fresh air has free access to the room. If possible, it is desirable to sleep in an outside porch properly protected from storms. In case a porch is not available, the windows of the sleeping room should be kept open.

In the second place, we should make sure that the organs of respiration are in a normal condition. One of the most common errors is breathing through the mouth instead of the nose. This is due usually to the stopping of the nasal passage by enlarged tissues, called *adenoids,* that develop in the upper part of the pharynx. Adenoids should be removed by the surgeon, since they not only prevent the access of air to the lungs but also cause a vacant expression of the face, and may produce deafness.

Deep breathing should be practiced daily. This habit may be promoted by exercise in various forms, such as brisk walking, work, and games of different kinds. Persons working in an atmosphere where dust prevails are likely to have the tissue of the lungs injured, thus making them more liable to disease. Soot and smoke are irritating to the throat as well as to the lungs.

Diseases of the Respiratory System.—Colds and catarrh are two of the most common diseases that attack the air tracts. A cold is an inflammation, usually due to the presence of bacteria, or tiny germs. It may occur in the nose cavity or in the throat. If it attacks the larynx, it affects the vocal chords and causes hoarseness. If it affects the tonsils, it produces tonsilitis. If it extends to the bronchial tubes, it causes bronchitis, and when it attacks the air sacs of the lungs, it produces pneumonia, a very dangerous disease.

Catarrh is also an inflammation of the mucous membranes of the throat and nose and may extend to the inner ear, causing deafness, or to other parts of the body, causing various disorders.

Another disease that affects the respiratory system is tuberculosis, which may be prevented by proper attention to diet, method of breathing, food, exercise, and rest. Diphtheria, still another disease that affects the throat and nose, is due to a specific form of bacteria that has the power to produce a dangerous *toxin,* or poison. In recent years this disease has been more or less controlled by the injection into the blood of an *antitoxin,* a substance that counteracts the poison. Whooping cough also affects certain parts of the respiratory system.

Ventilation.—To ensure the proper ventilation of a room, there should be a constant supply of fresh air, heated to a suitable temperature, properly moistened, and an outlet to carry away foul air. The supply of fresh air must be sufficient to replace the oxygen taken up by the occupants of the room in respiration, and to absorb and remove the carbon dioxide they give off. Recent experiments indicate that under ordinary conditions, even when ventilation is poor, the air will not become so unwholesome as has heretofore been supposed, provided it is kept in motion and due

attention is given to the temperature and to the regulation of the amount of moisture present.

Methods of Ventilation.—The simplest way to ventilate a room is by opening the windows, both at the top and bottom,

Brown Brothers.

A Warning of Invisible Danger

A canary is extremely sensitive to foul air. If there are poisonous gases in a mine the bird will quickly die, warning the miners that they are in danger.

thus allowing free circulation of air. This method, however, can be used with safety and comfort only in warm weather. Even ther ·t is wise to prevent direct drafts by placing a window board

across the window sill with the lower sash slightly raised. This throws the air current upward and prevents its blowing directly on the occupants of the room.

The placing of a muslin screen over a window opening will prevent too strong a draft and yet permit a sufficient flow of air into a room.

An open fireplace is desirable in every living room. As soon as the fire is lighted, the current of air up the chimney draws the stale air from the room. This air is quickly replaced by fresh air that will enter through any opening, however small.

The problem of securing adequate ventilation in public halls, school rooms, and large buildings is an important one. Modern ideas of ventilation demand the removal of all unhealthy gases and odors, the introduction of a certain amount of moisture, the constant movement of the air, and the maintenance of a proper temperature, as well as the introduction of fresh air. It is often necessary to force air into the rooms by motor-driven fans in the basement, through a *humidifier,* which moistens the air.

Hot air pipes in ventilating flues and revolving fans placed at the top of the flues are used to draw out the impure air. These devices must work in harmony with the heating plant of the building in order to secure the right temperature. When the entire system works as it should, the foul air and dust will be eliminated from the building and its place taken by a constant flow of fresh air, properly moistened and warmed.

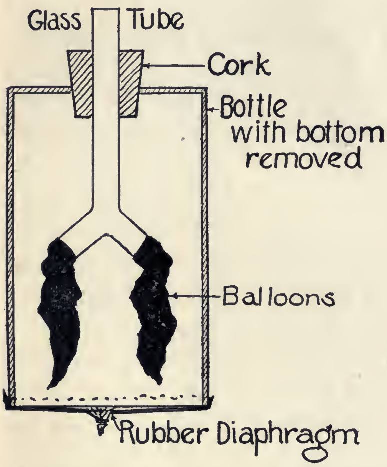
Experiments Related to Respiration.—

Experiment to Prove That Heat Is Generated in the Body.—Note the temperature of the room. Place a clinical thermometer under your tongue to find the temperature of your body. Now exercise violently for two minutes. Again take the temperature of your body. Has it increased? Has the temperature of the room increased? Do you conclude that heat is generated in the body?

Experiment to Show That Carbon Dioxide Is Produced in the Body.—Breathe into a test tube or bottle of lime water.

Notice that the lime water becomes milky in appearance. Carbon dioxide, a waste gas thrown off by breathing, causes the change in the lime water.

Experiment to Illustrate the Action of the Lungs and the Diaphragm in Breathing.—Remove the bottom from a large water bottle. Insert a Y-tube into the bottle, passing the upper end up through the cork of the bottle after attaching a small balloon to each branch of the tube. Adjust the tube so that the balloons will be suspended free in the bottle. Then tie a piece of sheet rubber, to the middle of which a cord has been attached, over the opening in the bottom of the bottle. The rubber represents the diaphragm and the balloons the lungs. When the cord is pulled the rubber will come down and the air pressure in the bottle will be reduced. The balloons will immediately expand, owing to the air pressure down the tube. When the rubber returns to its former position the air in the balloons will pass out through the opening in the tube and they will become less rigid. How does this experiment represent the action of the lungs and diaphragm in breathing?



Apparatus to Show the Process of Breathing

SUMMARY

Respiration is the life process by which energy is made available in the body. It includes breathing and oxidation.

Breathing is the process by which air is taken into the lungs and carbon dioxide is removed from them.

Oxidation in the body is the combining of oxygen taken from the air with food substances in the cells. It releases energy for the body's needs.

The principal organs of respiration are the diaphragm, the ribs, the lungs, the red corpuscles of the blood, and the cells of the body.

The diaphragm is a dome-shaped muscle attached to the ribs, forming the floor of the chest. By expanding and contracting, it aids in breathing.

The lungs are two sponge-like organs composed of minute air tubes, air sacs, and capillaries. They are located in the chest and are protected by the ribs, the breast bone, and the pleura. They are flexible to allow for expansion and contraction in breathing.

The red corpuscles are blood cells that carry oxygen.

The nose, pharynx, larynx, trachea, and bronchi form a continuous passage through which air reaches the air sacs of the lungs. The trachea is the main portion of this passage. At its lower end it divides into the bronchi which give off branches ending in the air sacs of the lungs.

Artificial respiration is the production of respiration by some means outside the body.

Tobacco smoke irritates the throat. If inhaled into the lungs, nicotine, a poisonous substance in the tobacco, may be absorbed into the system.

Alcohol causes enlargement of the capillaries of the lungs, producing congestion.

Healthy respiration depends on the free access of oxygen to all the cells of the body.

Breathing through the mouth should be avoided. Deep breathing should be practiced.

The principal diseases of the respiratory system are colds, catarrh, diphtheria, tuberculosis, pneumonia, and whooping cough.

Ventilation is necessary in order that fresh air may constantly be brought into, and foul air removed from, the rooms where people live.

Fact and Thought Questions

1. Why is respiration necessary?
2. Describe the action of the ribs and the diaphragm in breathing.
3. Describe the lungs. Show their adaptation to their work.

4. Why does breathing tend to become more difficult and more rapid as one ascends a mountain?
5. Why is exercise in fresh air more beneficial than exercise in an ordinary closed room?
6. Is the air you breathe on the street necessarily health-giving?
7. If forced to pass through a smoke-filled room, would you breathe deeply? Why?
8. Describe the Schaefer method of artificial respiration.
9. Does a crowded auditorium require less or more heat than an empty one to maintain a warm temperature? Why?
10. Under what conditions are automobiles dangerous to respiration?
11. How may the presence of carbon dioxide in expired air be shown?
12. State the effect of the use of alcoholic beverages on the lungs.
13. State the nature, location and effects of adenoids.
14. State the parts of the respiratory system that are most liable to each of the following: tuberculosis, catarrh, pneumonia, diphtheria.
15. How do you ventilate your room at night?
16. Describe a good method of house ventilation.
17. Why should one always breathe through the nose?
18. Give two reasons why deep breathing under ordinary circumstances is healthier than shallow breathing. Can you think of any particular circumstance in which it would be wiser not to breathe deeply?
19. Why do people stamp their feet, swing their arms and exercise in other ways, when cold?
20. Why are climbers forced to rest at frequent intervals when climbing high mountains?
21. Name in their proper order the parts of the continuous air passage leading from the nose to the air sacs of the lungs.
22. Why is the inhaling of tobacco smoke unhealthy?
23. Carbon monoxide gas attacks the red corpuscles of the blood. How would breathing this gas affect the body?

Projects

1. Examine the lungs of a frog or other animal in order to understand better the structure of your lungs.
2. Devise a simple experiment to show the necessity of oxygen to sustain life.
3. Prepare a set of rules for proper breathing.
4. Investigate the Sylvester method of artificial respiration, and the use of the pulmotor for the same purpose. Write a report comparing the Schaefer method with either of these.

Outdoor Observation

On the way to school,

(a) Practice deep breathing and note effects.

(b) Walk slowly, walk rapidly, and run, fairly equal distances. Note effects on rate and depth of breathing.

References

The Human Mechanism............................*Hough and Sedgwick*

CHAPTER XXVI

FOOD VALUES

Always, man has had to eat to live. In earliest times his main energies were devoted to hunting and gathering food. Even today, with all our modern knowledge and appliances, a large part of our population is engaged in raising, gathering, and preparing food, and in transporting it throughout the world to those who need it.

Once man's body was the only machine he had to help him. Now he makes machines by which he controls the forces of nature. But, though his own physical effort is lessened as a result, his own bodily machine is just as important to him as ever. It must not only be kept alive, but it must be kept in good running order, and be fed the right food fuel that it may produce the greatest energy possible.

It is clear, then, that one of our most important acts is eating. Careless eating, overeating, or eating the wrong food may clog our bodily machinery, causing it to lose strength and efficiency. For our comfort, success, and best usefulness we need to know how and what to eat.

In the constant motion of the muscles and in the activities of all the other organs of the body, there is a continual loss of heat and of the material of which the body is composed. In consequence of this loss, the tissues must be renewed and new force provided to keep them in action. Otherwise all the muscles will waste away and all activity will cease. Hence the necessity of a constant supply of new substances that will furnish building material and energy. These substances are called *food.* Food may be defined as a substance containing material necessary for the growth of the cells of the body, or as the fuel that, when oxidized, produces the energy needed to carry on the processes of the body. Any substance that is unable to accomplish one of these purposes cannot properly be called food.

Food Substances or Nutrients.—There are six food substances: *proteins, carbohydrates* (starch and sugar), *fats* and *oils, mineral matter, water,* and *vitamins.* All of these substances enter into the composition of the human body.

Proteins.—Proteins form an essential part of protoplasm and are therefore absolutely necessary for the growth and the repair of all living tissues. They also produce energy when oxidized in the body. The most important foods containing proteins are lean meat, milk, cheese, fish, white of eggs, or albumen, and certain seeds, such as beans and peas.

The chemical elements that enter into the composition of proteins are nitrogen, hydrogen, oxygen, carbon, and sulphur. Animal proteins emit an offensive odor when they decompose. The most important element in all proteins is nitrogen. Proteins are often called *nitrogenous* or *albuminous* foods.

Fats, Oils, and Carbohydrates.—Just as proteins provide the material for the growth and repair of tissue, so fats, oils, and carbohydrates furnish most of the material which, when oxidized, supplies the energy necessary for the body. The most important foods containing fat are butter and meats. All meat foods contain some fat. Milk, cheese, the yolk of eggs, and many seeds, such as cotton seed and flax seed, and nuts yield fat and oil. The most important carbohydrates are starch and sugar. All carbohydrates are of vegetable origin and are found in fruits, grains, seeds, roots, tubers and, to some extent, in other parts of plants. All fats, oils, and carbohydrates are made up of various combinations of carbon, oxygen, and hydrogen.

Mineral Matter.—The most important mineral substances needed by the body are *phosphates, carbonates, sulphates,* and *nitrates,* used in the making of protoplasm, bones, and teeth. These substances form a part of green vegetables and grain cereals. Common salt also is important, since it is needed in the digestive fluids and renders food more palatable, or pleasing to the taste.

Vitamins.—*Vitamins* is a word which has recently come into use to designate various unknown substances in foods that appear to be necessary to the maintenance of perfect health in the body.

It has been observed that people who live on a restricted diet of only a small variety of foods do not always enjoy the best of health, even though they have a sufficient quantity of all the five nutrients—protein, fats, carbohydrates, water, and mineral matter. This has led to the theory that there are certain substances, called vitamins, which are required by the body, although their nature is not yet understood. They occur in many food substances, including milk, eggs, fresh vegetables, and fruits. It is claimed that vitamins are sometimes lost to us because of the way we prepare foods, as by removing the outer covering of wheat in making flour, or by discarding the skins of potatoes. The absence of vitamins is supposed to cause scurvy which was formerly the bane of sailors who went on long cruises and were obliged to live on a meager variety of diet. In order to supply vitamins, there should always be a moderate amount of uncooked foods in the diet, such as raw fruits, tomatoes, and green vegetables. The juice of oranges is recommended by physicians for infants, to supply vitamins in their diet. Sunlight contains a vitamin which enters any body exposed to it.

Experiments to Show the Characteristics of Some Nutrients and Their Presence in Commom Foods.—Certain chemicals produce characteristic changes in food substances, and consequently may be used to show the presence of these substances in different kinds of food. For example, iodine solution is a test for starch. If starch is present in a food tested with iodine solution, a blue color will be produced. Fehling's solution is a test for grape sugar. If grape sugar is present in a food Fehling's solution will produce a color varying from yellow to brick-red according to the amount of sugar present. Nitric acid is a test for protein. If protein is present, the acid will produce a yellow color which will become orange if drops of ammonia are added.

In making tests for fat, for water, and for mineral matter, it should be remembered that white paper rubbed with a food containing fat will appear translucent when held before the light; that if food containing water is heated, the water will evaporate and condense on a piece of cold glass held over it; and that substances containing minerals leave ashes when burned.

To Test Foods for Starch.—Boil a small amount of cornstarch in water in a test tube, and then add a few drops of iodine. Observe what happens and state your conclusion. Boil other nutrients in the same manner, add drops of iodine, and state conclusions.

To Test for Grape Sugar.—Boil a few grapes in water in a test tube, or boil grape sugar in solution in a test tube. Into this tube pour some Fehling's solution. Observe what happens and state your conclusion. Boil other food substances, treat them in the same manner, and state conclusions.

To Test for Protein.—Boil a small amount of white of egg in water in a test tube, shake the solution and add a few drops of nitric acid, noting the change in color; then add a few drops of ammonia and note the further change. State your conclusion. Test other food substances in the same manner and state conclusions.

To Test for Fats and Oils.—Put a drop of olive oil on a sheet of paper and leave it in a warm place. After a few minutes hold the paper before the light. Note what has happened and state your conclusion. Test other nutrients in the same manner and state your conclusions.

To Test for Water.—Hold a piece of cold glass over a test tube containing boiling water and notice that water vapor forms on the glass. Heat in a dry test tube a small piece of animal or vegetable food you desire to test for water and hold a piece of cold glass over it. Observe what occurs and state your conclusion.

To Test for Mineral Matter.—Burn the food to be tested in an iron spoon. Observe what remains in the spoon after the substance has thoroughly burned and state your conclusion.

To Test for an Acid or Alkaline Substance.—Some people suffering from an acid condition of the stomach must avoid acid foods and eat more alkaline foods. Litmus paper enables one to test foods for acids or alkalis. Acid substances will turn blue litmus paper red. Alkaline substances will turn red litmus paper blue.

Importance of Water.—The importance of a supply of water, free from impurities of a harmful nature, cannot be

Nutrients

Name of Nutrient	*Elements that make up Nutrient*	*Uses of Nutrient to the Body*	*Some Foods that Provide Nutrient*
Starch (carbohydrate)	Carbon, oxygen, hydrogen	Releases energy when digested and oxidized. May be changed into body fat	All vegetable foods
Sugar (carbohydrate)	Carbon, oxygen, hydrogen	Releases energy when oxidized. May be changed into body fat	Fruits, vegetables, such as beets and carrots, milk
Fats and Oils	Carbon, oxygen, hydrogen	Releases energy when oxidized. May be changed into body fat	Butter, cheese, mutton, milk and other animal foods; olive oil, nuts, grains and seeds
Water	Oxygen, hydrogen	Forms the fluids that carry food and air to the cells, and removes wastes	Is a part of all foods
Protein	Oxygen, hydrogen, nitrogen, carbon, sulphur, calcium, phosphorus, iron, potassium, sodium, magnesium	Essential to the making of protoplasm, builds tissue, releases energy when oxidized	Animal foods, especially lean meats, milk, cheese and eggs; vegetable foods, especially cereals
Mineral matter	Compounds made up of the elements named above	Essential in making protoplasm, bones and teeth	Grains (whole), milk, meats, fish, eggs, green vegetables and fruit
Vitamins	Unknown	Necessary to the well-being of the body. Prevent certain diseases	Milk, grains (whole), green vegetables and fruit, eggs, nuts

over-estimated. Water is indispensable to life. It constitutes over sixty per cent of the weight of the body. Without its aid as a transporting agent the cells of the body cannot be supplied with food, and the wastes of the body cannot be carried away, for food is available to the cells only when in solution, and wastes cannot be removed from them unless in soluble form.

In ordinary water there are always some harmless germs. Sometimes there are disease germs which thrive on decaying animal matter in water. Such germs usually find their way into the

water when the source of water supply is near drains or places where sewage has been emptied. It is a well known fact that typhoid fever is often spread in this way. As water that contains disease germs may appear to be clear, tasteless and even odorless, it is advisable to have the supply examined occasionally by an expert.

International Newsreel.

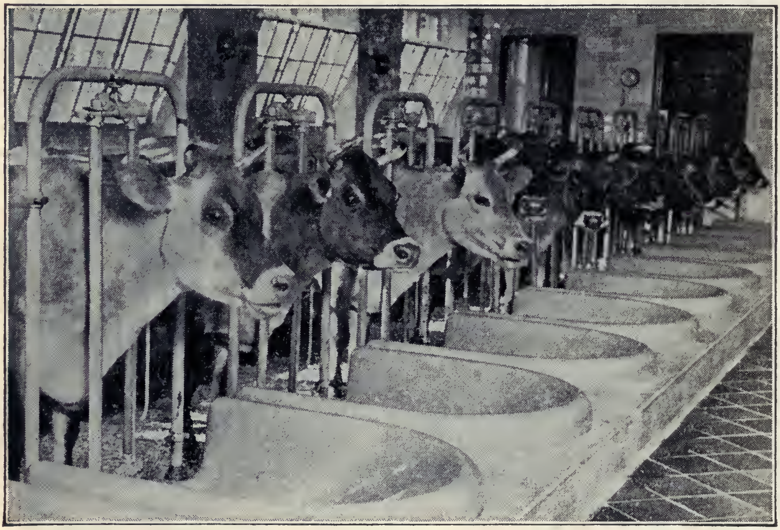
SAFEGUARDING THE WATER SUPPLY OF A GREAT CITY

The chemist is testing the water for harmful substances.

Importance of Pure Milk.—Of all the foods furnished by animals, milk is more nearly a complete food than any other, as it contains all the nutrients in about the proper propor-

tion to sustain life. It is considered a perfect food for children, but has not quite sufficient carbohydrate material for adults.

Owing to the fact that milk is easily contaminated and disease germs multiply rapidly in it, the greatest care should be taken to keep it free from all impurities. The origin of an epidemic of an infectious disease, such as typhoid fever, is often traced to a source of milk supply where there has been a case of such disease. Sometimes the cows themselves, from which the milk came, are



Ewing Galloway

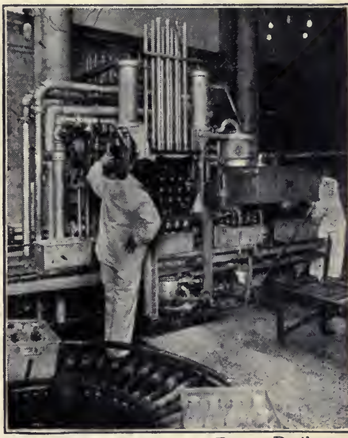
A Source of Pure Milk

Healthy cattle in clean surroundings.

found to be the source of the germs that caused the sickness. In progressive cities and towns, in order to protect the consumers, Boards of Health have adopted milk standards so as to insure the production and sale of pure milk.

Food Accessories.—In addition to the nutrients already referred to, certain substances, sometimes spoken of as food accessories, are extensively used. These include condiments, or seasonings, such as pepper, cinnamon, nutmeg, mustard,

and flavors like vanilla and lemon extract. Tea, coffee, cocoa, and various forms of alcoholic drink might also be included in the list of food accessories. Some of them, such as cocoa, undoubtedly have a little food value, but most of them act merely as stimulants. The question whether a drink containing alcohol is a food or a poison has been the cause of much discussion. Experiments seem to prove that it is not a food, or at least not a desirable food.



Brown Brothers.

A Modern Milk Plant Where Cleanliness is the Rule

Fuel Value of Food.—The *fuel value* of any food is measured by the amount of energy it is capable of furnishing when it unites chemically with oxygen in the body. Just as energy is released by the burning of wood in a stove or coal in the firebox of an engine, so it is released by the oxidation of food in the cells of the tissues.

The food which we eat, after it is digested and absorbed into the cells of the body, comes into contact with the oxygen which reaches the cells through the blood. The food is oxidized by the oxygen, and heat and other forms of energy necessary to carry on life processes are released. The total amount of heat finally given off represents the fuel value of the food taken. This value as a source of energy is measured in heat units. A heat unit is called a *Calorie* (C).

Calories.—A Calorie is the amount of heat required to raise the temperature of 1000 grams of water one degree Centigrade, or of one pound of water four degrees Fahrenheit. Since the heat value of any food is expressed by the number of Calories it contains, the daily food requirement of an individual may be determined by the use of Calorie tables, provided his daily fuel need is known. Remember, he must fully replace his output of heat in order to continue his efficiency.

Conditions of Muscular Activity.—The following table indicates the average normal output of heat per hour from the body of an average-sized man (154 pounds):

	Average Calories per Hour
1. Man at rest, sleeping	65
2. Man at rest, awake, sitting up	100
3. Man at light muscular exercise	170
4. Man at moderately active muscular exercise	290
5. Man at severe muscular exercise	450
6. Man at very severe muscular exercise	600

Muscular activity has a great influence on the amount of heat energy given off by the body. A man doing office work gives off only about 170 Calories an hour, and therefore has to eat only sufficient food to replace that heat. Should the same man become a farmer and do farm work requiring considerable muscular effort, he would need to replace about 290 Calories an hour, and if he went into the wilderness and became a woodsman, working hard all day swinging an axe, he would increase his hourly heat output to about 600 Calories, and would be forced to eat much more food than formerly, or food with greater heat value. One's diet should, therefore, depend largely upon one's activity.

Food Allowances for Children.—The following table is based on *Food Allowance for Healthy Children,* a publication of The Association for the Improvement of the Conditions of the Poor, New York City.

Age Years	*Calories per Day*		*Age Years*	*Calories per Day*	
	Boys	*Girls*		*Boys*	*Girls*
Under 2	900–1200	900–1200	9–10	1700–2000	1550–1850
2–3	1000–1300	980–1280	10–11	1900–2200	1650–1950
3–4	1100–1400	1060–1360	11–12	2100–2400	1750–2050
4–5	1200–1500	1140–1440	12–13	2300–2700	1850–2150
5–6	1300–1600	1220–1520	13–14	2500–2900	1950–2250
6–7	1400–1700	1300–1600	14–15	2600–3100	2050–2350
7–8	1500–1800	1380–1680	15–16	2700–3300	2150–2450
8–9	1600–1900	1460–1760	16–17	2700–3400	2250–2550

The boy who plays baseball requires a larger amount of food than the boy who merely watches the game, and the girl who plays on the basketball team requires more to eat than the girl who does only embroidery work.

The table given applies to boys and girls of average weight. In cases where the boy or girl is somewhat over or below average weight, allowance should be made accordingly in determining the number of Calories necessary per day, since greater weight demands more Calories and smaller weight less Calories.

The following table, compiled from data in *Feeding the Family,* by Doctor Rose, indicates the number of Calories usually required daily for each pound of weight during the growing period:

Age	*Calories Needed Per Pound*
Under one year	40–45
During the second year	40–43
During the third year	37–40
During the fourth year	37–40
During the fifth year	35–37
During the sixth year	34–35
During the seventh year	32–34
During the eighth year	30–35
During the ninth year	30–35
During the tenth year	28–32
During the eleventh year	28–32
During the twelfth year	28–32
During the thirteenth year	25–30
During the fourteenth year	20–25
During the fifteenth year	20–25
During the sixteenth year	20–25
From the seventeenth year on	according to activity

The Daily Diet.—We lead such varied lives that no one model diet can be made for all families. Conditions of occupation, climate, available food supplies, and health are markedly different. The city family may require much less food than a farmer's family, whose members are constantly doing work requiring much muscular effort. People like the Esquimos, living in a very cold region, need a larger amount of food that will produce heat than people like the Hottentots, who live in a torrid climate. Surely a

woodchopper needs a larger amount of energy-producing food than a student, who is less active physically. It is, however, practical for each family to plan its own diet to suit its own needs. The diet must be well balanced, containing a good proportion of each nutrient, whose total heat value should be regulated according to occupation, climate and health.

When we consider that the body uses protein and mineral matter for growth and repair, and carbohydrates, fat, and protein for fuel, and that water makes up a large percentage of the body, the necessity for a mixed diet is apparent.

In order to meet exactly the requirements of the body, a diet should not only be mixed but should also be well selected. A well-selected diet is one calculated to provide the different nutrients in proper proportions to supply a person with the food necessary for growth and repair of tissue, and to produce sufficient energy to perform his daily work as well as to carry on his life processes.

Diet for Growing Boys and Girls.—Special care must be taken in planning the diet for boys and girls of school age. They need more food per pound of weight than adults do. Not only must they replace worn out cells but they must also build new ones, as they are constantly growing in size and weight. Children must have foods rich in protein to build up their body cells, foods rich in mineral matter to make bones and teeth as well as cells, and foods rich in fats and carbohydrates to provide energy for ceaseless activity. Boys over ten years of age usually require more food than girls of the same age, and both use a larger proportion of protein for the building of new tissues than adults.

Most young people, as well as adults, undoubtedly eat more protein food than they need. Unlike other foods, excess protein food is not stored in the body and must be eliminated. Is it not better, then, to avoid eating more of it than is required? There is usually no danger of not getting sufficient protein in one's diet. There is more apt to be lack of sufficient kinds of food that contain calcium, needed for bone making, iron, which enables the red blood corpuscles to pick up and carry oxygen to the cells, phosphorus, needed for the healthy growth of cells, and vitamins, an essential for good health. In selecting food, bear in mind that

milk, cheese, egg yolk, and almonds are among the foods rich in calcium; that egg yolk, white bread, whole wheat bread, cheese, and oatmeal are among the foods rich in phosphorus; that egg yolk, oatmeal, whole wheat bread, spinach, lean beef, and almonds are among the foods rich in iron; and that milk, eggs, green vegetables, and fresh fruits are rich in vitamins.

In order to insure a well-selected diet, a standard for measuring food is necessary. A convenient standard is the amount of food required to yield one hundred Calories, since it corresponds quite closely to the ordinary portion of a number of foods.

Tables issued by the United States Department of Agriculture have been prepared, showing the amounts of different kinds of food which yield one hundred Calories. Some of these amounts are shown in the following table. By reference to it one can readily determine whether his daily diet gives him sufficient Calories for healthy living.

Food	*Measure*
Shredded wheat	1 biscuit
Oatmeal	1 large dish
Graham bread	1 thick slice
White bread	1 thick slice
Dry toast	1 thick slice
French roll	1 roll
Graham crackers	2 large
Griddle cakes	1 cake
Corn muffins	1 muffin
Baking powder biscuit	2 small ones
Lamb chop	1 small one
Hamburg steak	1 small cake
Chicken, broiled	1 good-sized slice
Rib, roasted	1 good-sized slice
Bacon, fried	4 small slices
Oysters	1 dozen
Tuna fish, canned	½ cup
Potato	1 medium size
Lettuce	2 large heads
Tomatoes, fresh	2 large
Tomatoes, canned	2 cups
Spinach, cooked	3 cups
Sweet corn	1 ear, medium size
Peas, canned or fresh	¾ cup

Food	*Measure*
Milk, whole	5/8 cup
Butter	1 tablespoon
Egg	1 very large one
Omelet	1 egg
Cheese, American	Small piece, cube 1 1/3 inch
Sugar, granulated	2 tablespoons
Honey	1 tablespoon
Pie	1/3 of an ordinary piece
Almonds	14 to 18 nuts
Peanuts	1 dozen
Peanut butter	1 tablespoon
Olive oil	1 tablespoon
Apple	1 large one
Banana	1 medium size
Orange	1 large one
Grapefruit	1/2 medium size
Dates	4 to 6 according to size
Prunes	4 to 6 according to size
Olives	5 to 7 according to size
Lemons	3 large ones
Tomato soup (cream of)	3/8 cup
Ice cream	1/4 cup
Chocolate cake	1 piece
Fruit salad, 1/2 tablespoon dressing	1/4 cup

The following table is an example of how the required Calories may be distributed among foods containing the various nutrients so as to provide a well-balanced diet:

Suggested Daily Diet for Ages 14 to 18 Years

Breakfast	*Calories*
Fruit	50 to 100
Cereal	100 to 200
Milk	150 to 200
Bread	200 to 300
Butter	100 to 200
Total	600 to 1000

Luncheon	*Calories*
Eggs	75 to 150
Bread	200 to 250
Butter	100 to 200
Milk	100 to 200
Fruit	50 to 150
Total	525 to 950

Dinner	*Calories*
Tomato soup	100 to 200
Meat	100 to 200
Potatoes	100 to 200
Green vegetables	25 to 75
Bread	200 to 325
Milk	100 to 200
Fruit salad with dressing	100 to 200
Chocolate cake, 1 piece	100 to 200
Ice cream, 1/4 cup	100 to 200
Total	925 to 1800
Total for day	2050 to 3750

SUMMARY

There is necessity for a constant supply of new substances to furnish building material and energy for the body.

Food may be defined as a substance containing material necessary for the growth of the cells of the body or for the production of energy.

There are six food substances or nutrients—proteins, carbohydrates, fats, water, mineral matter, and vitamins.

Food should be so prepared as to make use of the vitamins.

The importance of a supply of pure water cannot be overestimated. It is indispensable to life.

Milk is more nearly a complete food than any other substance. It is necessary to take great care to keep milk free from impurities.

The fuel value of a food is measured by the amount of heat energy it furnishes. This heat energy is measured in Calories (C).

The Calorie is the amount of heat required to raise one pound of water four degrees Fahrenheit.

The daily food requirement of an individual may be measured in Calories if his age, weight, and daily work are known.

The body needs a well-selected mixed diet.

A standard of measurement is necessary in order to insure a well-selected diet. The amount of food required to yield one hundred Calories is a convenient unit of measurement.

Fact and Thought Questions

1. Name the six classes of nutrients and state the use of each to the body.
2. Name several plant and animal food products raised in your neighborhood. What nutrients does each supply?
3. Why do you eat more after playing or working hard?
4. How does climate affect the kinds of food you eat?
5. Discuss the importance of water to the body.
6. Why is milk considered a perfect food for children?
7. Mention a test for each of the nutrients.
8. In what foods are vitamins found?
9. Discuss the necessity of a well-selected mixed diet.
10. Define Calorie.
11. Give the number of Calories required per hour by a man at light muscular exercise; at moderately active muscular exercise.

12. Why shouldn't a community have a standard ration as an army does?
13. Suggest how a mountain climber's diet might differ from that of a man engaged in intense mental labor.
14. Is it true or false that food is fuel? Why?
15. Complete this statement: Fats give much ———— to the body.

Projects

1. Make tests to find out what nutrients are present in the foods you eat on a certain day and record results in your notebook.
2. By referring to tables of food values, prepare a daily diet adapted to your needs, including needed nutrients and sufficient Calories.

Outdoor Observation

Walk by a grocery store and a market and observe what fresh foods are on display. List ten of them in order of fuel value.

References

The New Knowledge of Nutrition............................*McCollum*
Feeding the Family..*Rose*
Vitamins ....*Harrow*

CHAPTER XXVII

FOOD AND ITS PREPARATION

The primitive savage gathered food where he could find or capture it, and ate it raw to satisfy his hunger. He ate heavily when he had an abundance of food, knowing no way to preserve what he could not eat. After the discovery of fire he learned, by slow degrees, to cook food. He discovered that this made it taste better and last longer. He had no idea, however, that he had made a real health discovery.

It is science that has taught us that proper cooking not only makes food more appetizing and preserves it longer, but that it makes it better fuel for our bodies. Cooking breaks down tough food fiber and causes chemical changes that make food digest better and yield more energy. It enables us to eat food with a high nutritive value which we could not, or would not, eat raw. It protects health by destroying dangerous germs that if taken into the system alive would cause disease. Naturally, having studied the selection of food, we should know the important facts about its preparation for use.

The variety of ways in which foods are prepared and served in restaurants and on the tables of those who are able and willing to pay for them is almost endless. It would be impossible to enumerate them. There are, however, a few general principles related to all cookery that should receive consideration. Important among these are the effects of cooking, and the chemical reactions produced by yeast. Though some foods, like milk and various kinds of fruits and vegetables, if obtained from sources that are sanitary, may safely be eaten raw, most animal and vegetable food should be cooked.

Why Animal Food Should Be Cooked.—Animal food should be cooked so that the digestive juices of our bodies may act readily on it. Much animal food consists of muscular tissue which is much more easily chewed and digested if it is first softened by cooking. Animal food, moreover, sometimes contains small organ-

isms that produce disease in the human system if they once gain entrance. Among these are tapeworms, trichinæ, or pork worms, and harmful forms of bacteria. These are destroyed in food that is adequately cooked. Then, too, properly cooked meat has a more desirable flavor and is more pleasing to the eye.

Different Methods of Cooking Meat.—There are several methods of cooking meat. *Roasting* and *broiling* are commonly considered the best, since they cause less loss of nutritive material than other ways of cooking. By these methods the juices are retained in the meat, except for a small portion that escapes into the pan. A good cook frequently pours over the surface of the roast the juices that escape, thus forming a better crust to protect the meat beneath from drying. This is called basting. In preparing a small roast, a high temperature may be used until the meat is cooked, but in cooking a large roast high temperature dries the portions near the surface too much before the inside is cooked. Consequently the high temperature is used only at first to coagulate, or thicken, the protein juices near the surface, and so to prevent the escape of the juices within. In roasting a whole ox, as at fairs or barbecues, the body is rotated on a horizontal spit over a fire. The constant pouring of melted fat over the slowly turning animal forms a crust which prevents the too great drying of the meat near the surface.

Other methods of cooking meat are *boiling, stewing,* and *frying.* The results sought in boiling meat are best accomplished by thrusting it at once into boiling water and allowing it to remain for a short time. This forms a crust by the coagulation of the protein in the outer surface and aids in retaining the juices of the meat. After this is done the water should simmer until the meat becomes tender, and the fibers can easily be separated. If carefully prepared in this way, meat becomes a very palatable food.

The results sought in stewing meat are quite different from those sought in boiling. In boiling, the main object is to retain all the juices as nearly as possible, but in stewing the purpose is to extract the juices from the meat as completely as possible. In stewing, the meat is allowed to simmer over a slow fire for a number of hours. In boiling the hot water acts as a carrier of the

heat; in stewing it acts as a solvent as well. The advantage of stewing is that in this way a very wholesome dish is prepared at a minimum cost. The juice of a small piece of meat stewed with a quantity of vegetables imparts its flavor to the whole dish, and requires much less fuel than roasting. This makes it desirable from an economic point of view.

Brown Brothers.

LEARNING THE BEST WAY TO PREPARE FOOD

Frying is commonly regarded as the poorest method of preparing meat. To fry a piece of meat is to cook it in hot fat. A hot fire is necessary, for unless there is sufficient heat to coagulate the surface of the meat the nutrient juices will escape and the hot fat will soak into the meat, making it difficult to digest.

Why Vegetable Food Should Be Cooked.—Just as all methods of applying heat change the condition of raw meat, softening the tissue and rendering it more easily chewed, so cooking

affects vegetable tissue. It causes the fibers to loosen, the starch grains confined in the cells to expand, and the covering of the cells, called cellulose, to burst, thus liberating their contents. Since cellulose is insoluble, it must be broken up or the contents of the cells cannot come into contact with the digestive fluids. In green vegetables, germs of a harmful nature are destroyed by cooking.

Chemical Reactions or Changes.—The only chemical change occurring in cooking that needs to be considered is the production of carbon dioxide in the making of bread. This has the effect of making bread light. It is usually brought about by the use of yeast which, in fermentation, yields carbon dioxide.

Economy in the Purchase of Foods.—Economy in the purchase of food means the spending of money, whether the amount is large or small, for the kinds of food that will provide the greatest amount of nourishment with the least expenditure of money. Food purchased at small cost is cheap only when it is capable of keeping the body in a high state of health. No food can be called cheap if its use causes illness, or lessens in any degree the efficiency of the body. It leads to doctors' bills and decreases one's ability to earn. It will always be found more economical to purchase food of high grade. This does not necessarily mean that the most expensive brands of food should be bought, but simply that whatever food is used should be of good quality.

It should always be borne in mind that the human body requires food which will produce energy, and also food which will replace tissue that is worn out. The best energy-building foods are sugars, starches, and fats, which are found in sufficient quantity in cereals, cereal products, potatoes, beans, peas, butter, fat meat, and oils. The chief material for the repair and building of living tissue is food containing protein. Protein comes from lean meat and the white part of eggs, and from grains and vegetables, all of which will also produce energy when properly oxidized in the body. Other materials, like lime, iron, and phosphorus, are also needed, but they are usually present in sufficient quantity in ordinary food substances.

Lack of economy in purchasing foods is often shown by using more meat than is necessary, for it is a mistaken idea that muscles need lean meat to make them work. Of course, a little meat is desirable to furnish protein for repair, but carbohydrates are the best food for the production of energy and are much cheaper than meat. Even the small amount of protein needed for repair can be obtained from vegetable food. From the point of view of economy, it should always be remembered that of all food stuffs that come into the home, meat is the most expensive.

In order to purchase foods intelligently, knowledge of proper planning of the diet is necessary, and this is often lacking. Among the things that should be known are the amount of energy used each day under varying conditions of climate, the kinds of work, the age, and the sex of those who are to be fed, and the value of the different common foods.

Economy in the Use of Foods.—The effort to economize should not cease with purchasing food, but should be continued in the using of it. The United States Food Administration stated that we as a nation eat eighty per cent more protein than we need. Much of this protein is meat. It is said that we are the greatest meat eaters among civilized nations. If it be true that there is no necessity for consuming meat in so great quantities, it would seem that the amount could be diminished in our diet with perfect safety to health.

Even when meat is served, there is often much waste caused by throwing away parts that contain considerable nutriment which might easily be used for making soup.

In preparing potatoes and other vegetables, care should be taken not to waste nutritious parts by cutting them off before cooking. It is claimed that the skins of potatoes and fruits contain the vitamins so essential to life.

The use of left-overs should not be neglected by the housekeeper who wishes to practice economy. Often fragments that might be used to advantage are put away in the icebox and forgotten until they spoil. Left-over meat and fish may be made into hash or chowder, left-over cereals may be fried or used in soups, and dry bread may be freshened by moistening the crust

and reheating in a covered dish. In fact, a skillful cook can make nearly every kind of left-over food palatable.

Adulteration of Foods.—Adulteration of food, according to the definition in the *Pure Food and Drugs Act,* passed by Congress in 1906, means:

1. The substitution, in whole or in part, of any substance for any article of food that would lower or injuriously affect the strength or quality of that food; for example, glucose, a sugar-like compound found in fruits or manufactured mainly from starch, is used for sugar.
2. The abstraction of any valuable constituent, in whole or in part, from an article of food; for example, fat from the cream of milk.
3. The coating or staining of an article of food whereby its inferiority might be concealed; for example, tea colored green with sulphate of copper.
4. The addition of any ingredient which might render an article of food injurious to health; for example, use of saccharin, an intensely sweet drug obtained from coal tar, to sweeten canned fruit.

A drug is deemed adulterated (1) if it differs from the recognized standard of strength or purity; (2) if its strength or purity falls below the professed standard or quality under which it is sold.

The term "food" includes all articles used for food, drink, confectionery, condiment, or relish. The term "drug" includes all medicines and preparations recognized by proper authority and intended to be used for the cure or prevention of disease. In the case of confectionery, it is considered adulterated if it contains talc or other mineral, any poisonous color or flavor, any spirituous liquor, any drug, or any other ingredient detrimental to health.

The law also requires manufacturers of food and medicines to make known on a label attached to the article the exact percentage of the substances it contains. This enables the buyer, by reading the label, to know what makes up the article he purchases.

Before this law went into effect milk, sugar, coffee, ice cream, and olive oil were frequently adulterated. Water was added to

milk, glucose to sugar, chicory to coffee, gelatin to ice cream, and cotton seed oil to olive oil.

SUMMARY

Animal food should be cooked to soften the tissues, to develop desirable flavor, to destroy germs, and to make it more digestible.

The principal methods of cooking are roasting, broiling, boiling, stewing, and frying.

Economy in the purchase of food aims to procure for the smallest amount of money the largest possible quantity of nutritious food. It is not economy to buy food of poor quality even at a low price.

Economy in the use of foods consists in eating only as much as the health of the body demands. The amount of meat in the daily diet may usually be diminished without injury to health. In the second place, economy consists in not wasting parts of food that contain nutriment.

Fact and Thought Questions

1. Name several foods you eat raw; several that are cooked; several manufactured, and at least partially cooked.
2. Why should food be cooked? Mention specific foods as examples.
3. Describe several methods of cooking and discuss the merits of each method.
4. Why not cook *all* foods?
5. How is the sun necessary to a food supply? How does it preserve foods?
6. What is the real explanation of the remark, "The sight of that food makes my mouth water"?
7. Does cooking ever make food worse for human consumption instead of better?
8. Name some foods that are especially useful in the production of energy.
9. Name several foods useful for the building of tissue.
10. Suggest ways of economy in the use of food.
11. Mention foods that may be eaten with safety without cooking them.
12. Is low-priced food always economical? Why?
13. State ways in which science has affected our food supply.
14. What is an adulterant? Name several and state for what food materials each is sometimes substituted.
15. What is the object of the Pure Food and Drugs act?

16. What information does the Pure Food and Drugs act require to be placed on foods sold in packages?
17. Why should we read the labels of package goods?
18. Compare boiling with stewing. Which process produces a more nutritious broth? Which retains the more nourishment in the meat?
19. State the object of a high temperature in roasting meats.

Projects

1. Describe the effects on food of the cooking you have seen at home or in camp.
2. Suggest methods of economy in the selection and purchase of foods.

References

Foods and Their Adulterations .... *Wiley*
Cost of Food .... *Richards*
Elements of Cookery .... *Williams and Fisher*

CHAPTER XXVIII

STIMULANTS

We sometimes hear stimulants spoken of as "whips" or "spurs." They drive our bodies to greater activity than they would naturally show.

With rare exceptions, stimulants are not really foods. Even if harmless, they do not provide the nourishment for the extra work which they demand. They do not build up real strength and energy. Like continued spurring, their steady use will drive our bodies to exhaustion and injure our nerves, our self-control, and our self-respect. We should all be on our guard against the dangers that may attend their use.

Stimulants is a term used to denote substances which, when taken into the human body, affect the nervous system in such a way that it reacts on the various organs under its control, and enables them to do more work than they otherwise would do. If the muscles have become exhausted by vigorous exercise, a stimulant is supposed temporarily to restore their ability to work or to continue work for a longer period. If the brain has become tired by long continued activity, it is thought that a stimulant may enable it to work for a longer time or for a period after it feels fatigue.

The most common substances used to stimulate the nervous system are tea, coffee, cocoa, and chocolate, and various concoctions that contain alcohol in a greater or less amount.

Tea and Coffee.—Both tea and coffee are much used as beverages. The stimulating effect which they produce on the nervous system is due to the presence of a drug, called caffein when found in coffee, and thein, in tea. The effect of tea and coffee is not the same on all persons. In some they produce indigestion, headache, and sleeplessness. In others they produce no harmful results, but seem to relieve physical and mental weariness. Neither tea nor coffee should be given to children.

The effects of tea and coffee, however, depend to a great extent upon the method of preparation. In addition to the drugs already mentioned, tea also contains an undesirable substance called tannin. While caffein and thein are easily made soluble and quickly diffused in hot water, tannin does not dissolve and will not diffuse in the solution to any great extent except when boiled for some time. Consequently tea should not be boiled.

Cocoa and Chocolate.—Cocoa and chocolate are also largely used. They contain a small amount of a substance similar to caffein, called theobromine, which might prove harmful if taken in large doses. The small amount that exists in these drinks, however, has practically no effect. Cocoa and chocolate used in moderate quantities are agreeable and wholesome beverages for most people. In addition, they have a food value since they contain a considerable quantity of albumin and fat.

Alcohol.—While alcohol has no food value, various kinds of beverages made from it are still extensively used in many parts of the world despite the most conclusive proof that these beverages, when taken habitually or in excess, are undoubtedly harmful. The steady use of alcoholic drinks shortens life and is the cause of much poverty, misery, and sickness.

Some of the effects of excessive drinking of alcoholic beverages have always been apparent. These include the loss of self-respect and of pride in personal appearance, the weakening of the will and the loss of self-control, the destruction or undermining of health, and the reduction of the working efficiency of the individual. Other noticeable effects are the suffering caused by poverty, the filling of poorhouses and hospitals for the insane, and the terrible effects of heredity as shown in the crippled organs and the defective senses of the young.

Fermentation.—Alcohol results from the fermentation of liquid solutions of sugar or of other plant products which contain sugar. Fermentation is a chemical change caused by yeast. Sometimes this fermentation is caused by minute yeast organisms which are always present in the air. In fermentation, sugar is changed to carbon dioxide gas, which forms bubbles and escapes, and to alcohol which remains in the liquid.

The fact that yeast is the real cause of fermentation was not clearly understood until the middle of the nineteenth century. At that time, Louis Pasteur, a very distinguished French scientist, definitely established the cause of fermentation by a long series of experiments.

Is Alcohol a Stimulant?—Until within a few years most authorities have maintained that alcohol in small doses is a stimulant, since it apparently incites the various organs of the body to greater activity. Now, however, there are many physiologists who insist that it is never a stimulant. These maintain that the apparent stimulating effect of alcohol is really a paralyzing influence on the nervous system, which lessens its restraining control over the actions of the body.

Why Alcoholic Beverages Are Used.—Since it is universally acknowledged that the use of alcoholic drinks has been the cause of much misery, pauperism, and insanity, the question at once arises as to why such drinks are used. It is claimed by some people that alcohol when taken into the system produces a certain amount of heat energy. Although when taken in small quantities alcohol may possibly act as a fuel and tide over a crisis in sickness, the danger that accompanies its habitual use is so great that it is unwise to employ it for such purposes. Habitual users of alcohol do not recover as readily from illness brought on by accidents or by surgical operations. People do not ordinarily drink alcohol because it produces heat energy; they drink it because of its taste, because of the excitement it produces and, finally, because they have acquired a habit of using it which they are not able to overcome.

While under its influence, users of alcohol are irresponsible and do not act quickly or accurately in mind or body. As a result they often endanger themselves and others. This is especially true of workers in many industries who are required to handle machinery and dangerous materials. Consequently men who drink find themselves restricted in their opportunities for work. In the heavy automobile traffic of today, drivers who are under the influence of alcohol are unable to operate cars

or trucks with due regard to the safety of others. They are therefore a menace on the public highways. The law everywhere penalizes such drivers as dangerous. They are liable to have their driving licenses suspended for long periods or to have them cancelled.

Wood Alcohol.—In speaking of alcohol we have made reference only to what is commonly referred to as grain, or ethyl, alcohol. There is another kind known as wood, or methyl, alcohol, manufactured from wood fiber. Of late years this has come into prominence owing to the widespread accounts in the daily papers of deaths caused by its use. Wood alcohol is used in shellacs and varnishes and as a fuel. It resembles grain alcohol in appearance but it is extremely poisonous.

SUMMARY

Stimulants is a term given to substances that affect the nervous system in such a way as to cause the organs of the body which it controls to do extra work.

The most common stimulants are tea, coffee, cocoa, chocolate, and various forms of drink that contain alcohol.

Tea and coffee, if properly prepared and used in moderate quantities, are not usually harmful to adults. They should not be used by children. Cocoa and chocolate used in moderate quantities are considered healthful.

The use of alcoholic beverages has always been a source of misery to humanity.

Alcohol results from the fermentation of liquid solutions of sugar or of other plant products which contain sugar. Fermentation is due to the presence of yeast.

Alcohol made from wood is used in shellacs and varnishes and as a fuel. It resembles grain alcohol but is very poisonous.

Fact and Thought Questions

1. What is a stimulant?
2. Are stimulants really foods?
3. Why is the right food better than a stimulant during a period of heavy work?
4. Why, if one is tired, is nourishing, easily digested food better than a stimulant?

5. Give some example from your own experience of the refreshing strength from some nourishing food after a period of exertion.
6. Define fermentation.
7. Why are alcoholic beverages used?
8. Name several non-alcoholic substances most commonly used as stimulants.
9. Suggest steps in forming a good habit.
10. In what ways is an automobile driver who drinks dangerous to others?
11. How does the habitual use of alcoholic drink affect the user's chances of recovery: (a) in case of an operation; (b) in case of accident?
12 What is wood alcohol? How does it differ from grain alcohol?

Projects

1. Write a composition on the evil effects of the use of alcoholic beverages on the human body.
2. Discuss the economic effects on a community where there is large use of alcoholic beverages.

References

Alcohol and the Human Body........................*Horsley and Sturge*
Physiological Aspects of the Liquor Question....................*Billings*

CHAPTER XXIX

NARCOTICS

Surely few of us would deliberately wreck our radio, or smash the delicate ignition system of our automobile, or puncture the diaphragm in our telephone, or permit easily-avoidable damage to any important apparatus that aids us in our work or adds to our comfort and pleasure.

Many a person, however, either deliberately or through lack of self-control, or because of ignorance of dangers involved, seriously damages that most important machine—his own body—unfitting it for its best service, or even destroying its usefulness. Exceptional harm is done when he permits injury to the delicate nervous system that controls the whole body, directing the work of the muscles and making him quick and sure in thought and action.

That is why it is vital that we know about the narcotics that cause slow destruction of the nerves, reduce our mental powers, and are able to destroy our success and happiness.

A *narcotic* is a substance that, when taken into the body or used on any part of the body, appears to affect the nervous system in such a way as to lessen the activity of the organs which it controls.

Narcotics have the opposite effect to stimulants. When used in small amounts they relieve pain, cause a feeling of rest, or produce sleep. When used in large amounts they may produce stupor or death. A dentist may use a small amount on the gums to deaden feeling when a tooth is extracted, or a smoker may use tobacco to produce a sense of restfulness after a day's work.

Sometimes a drug like opium is taken, which not only soothes pain but also produces a pleasant restful feeling. It seems an easy way to get relief from pain or fatigue. Accordingly, the user takes this remedy whenever he feels a pain. Small doses soon cease to bring relief and gradually he takes larger and larger doses to produce the effect he wishes. Unless he stops taking

the drug entirely, he reaches a point where he is never comfortable without it. He has then become an "opium eater."

The most common narcotics are *tobacco, opium, heroin, cocaine,* and *alcohol.*

Tobacco.—The tobacco of commerce is prepared from the dried leaves of the tobacco plant, an herb that belongs to the same family as the potato. It is extensively used and owes its narcotic effect to the fact that it contains a substance called *nicotine.* Nicotine is an oily liquid without color, and is one of the most active poisons known. This narcotic is soluble in alcohol as well as in water.

It is said that a single drop of nicotine placed upon the tongue of a serpent will cause its instant death. Two or three drops are considered sufficient to kill a man. The disagreeable sickening effect produced by the fumes of tobacco burned in an old pipe is due to the presence of nicotine. The nausea and discomfort often felt by persons when they use tobacco for the first time are caused by nicotine. These unpleasant feelings are nature's warnings against the use of the narcotic. Although only a very tiny quantity actually enters the system, nevertheless its action when first used clearly shows its harmful nature.

Why Tobacco Is Used.—Although its effects on the body are at first unpleasant, the nervous system soon becomes accustomed to nicotine and a feeling of sickness no longer follows its use. On the contrary, it apparently soothes the nerves and relieves the restlessness of fatigue. It is this agreeable reaction that constitutes the danger of its use. When the soothing effect passes away there is a desire for more, and if the habit of using it continuously becomes established, there will be taken into the body nicotine in sufficient quantity to injure permanently certain of the body tissues.

The Tissues Injured.—It is generally recognized that the use of tobacco in any form in early life interferes with the normal development of the heart, thus causing weakness in the adult. When used excessively by young or old it produces a nervous condition commonly known as tobacco heart. Furthermore, it causes irritation of the membranes of the throat and lungs and sometimes affects the eyes.

Ways in Which Tobacco Is Used.—Tobacco is used in chewing, in snuffing, and in smoking. In chewing, all the nicotine is taken into the mouth, a fact which may render it the most harmful way in which tobacco is used. If the saliva, laden with nicotine, is swallowed it cannot be other than harmful to the stomach and to the process of food digestion. It is not usually swallowed, however, for the user soon acquires the offensive habit of continuous spitting.

The custom of inhaling powdered tobacco through the nose is called snuffing. Happily this habit, so fashionable a century ago, is no longer indulged in to any extent.

When smoked, tobacco is placed in a pipe or rolled into a cigar or a cigarette. If the smoke is inhaled it may seriously injure the delicate tissues of the nose, larynx, trachea, and lungs. The smoking of cigarettes by the young is universally regarded as exceedingly harmful, not only on account of the nicotine poisoning, but also because the tobacco of which the cigarettes are made is sometimes steeped in a solution of opium. All boys should know that the cigarette habit produces mental inefficiency and, if persisted in, may lead to great deterioration of health and morals.

Effects.—Dean Briggs of Harvard said: "The peculiar evil in cigarettes I leave for scientific men to explain; I know merely that among college students the excessive cigarette smokers are recognized, even by other smokers, as representing the feeblest form of intellectual and moral life."

Dr. Andrew D. White, for twenty years President of Cornell University, summed up the matter as follows: "I never knew a student to smoke cigarettes who did not disappoint expectations, or, to use a vernacular expression, 'kinder peter out.' I consider a student in college who smokes, as actually handicapping himself for his whole future career. I am not fanatical in regard to smoking. It seems to me possible that men who have attained their growth and are in full health and strength may not be injured by moderate smoking at times. I will confess to you that at one period of my life I was a smoker myself, though in a very moderate degree. And should you feel a strong desire to smoke,

thinking it may rest you and change happily at times the current of your thought, I may perhaps commend to you my own example; for I began my smoking at the age of forty-five and ended it ten years ago at the age of seventy."

Statistics collected by Prof. Pack of the University of Utah indicate that athletes who use tobacco are inferior to those who abstain. After making a study of the tobacco-using habits of students competing for places on the football teams, he concluded:

1. That only half as many smokers as non-smokers are successful in the "tryouts" for football squads.

2. In the case of able-bodied men, smoking is associated with loss of lung capacity amounting to practically ten per cent.

3. Smoking is invariably associated with low scholarship.

Opium.—Opium is a narcotic prepared from the juice of the unripe seed capsules of the white poppy. It is a much more powerful narcotic than tobacco, and much more injurious to those who contract the habit of using it, as it not only injures the physical and mental powers but also causes deterioration of the moral sense of its victims. Like alcohol and other narcotics, its use creates a craving for more, which often leads to the opium habit, a habit which completely dominates the will. *Morphine, codein* and *heroin* are made from opium. Their use is a national peril. The habit of using these drugs is commonly formed by taking them to relieve pain, without realizing the danger thus incurred. The victim suffers from palpitation of the heart, oppressed breathing, insomnia and various mental disorders. The only safe way to avoid the evils resulting from this habit is never to take the first dose.

Heroin.—One of the most dangerous drugs, against the use of which a warning should be sounded, is heroin. Formerly it was made only from opium but now it is produced from coal tar. Speaking in regard to the danger involved in the use of this drug before the Committee on Education in the United States House of Representatives, the Hon. Walter F. Lineberger, representative from California, said:

"Though heroin is a comparatively new drug, the number of heroin addicts in one great city alone is estimated by the city

bureau of criminal identification at nearly 200,000, practically all of them below the age of 30, constituting nearly 60 per cent of the inmates of correctional institutions of that city.

"The heroin addict, at a certain stage of the drug effect, considers himself a hero and seeks heroics; not long afterwards, unless he can get more of the drug, he suffers from cramps, diarrhea, nausea, vomiting, and extreme depression.

"Scientific men, in view of the hopelessness of permanent cures, call drug addicts 'the living dead' and estimate that there are already so many addicts in this country that if placed in single file the line would extend from Boston, Mass., to Los Angeles, Calif.

"The alarming increase in drug addiction is due chiefly to the fact that the heroin addict has a mania for recruiting others and soon builds up a 'snow gang,' the drug being supplied him to give away free to the boys until they are 'hooked.' Soon the older members of the gang go forth and build up similar gangs. Formerly the expansion of drug addiction from opium, morphine, and cocaine was comparatively slow by process of addition; now the increase is galloping through a process of multiplication.

"The health commissioner of a great city of the Middle West, investigating the cause of the rising tide of crime, reported that girls and boys are appearing in the underworld by the thousands at very tender ages—14, 15, 16, 17—practically all of the girls and most of the boys having come by the swift drug road."

Cocaine.—Cocaine is made from the dried leaves of a plant called coca that thrives in South America. It is used largely as a relief for local pain. If absorbed into the blood, it affects the cells of the nervous system and deadens the sense of feeling. Used at first to relieve pain, when no longer needed for that purpose it is taken because it produces a soothing feeling. The habit, once formed, is difficult to overcome and, if persisted in, results in deterioration of the physical and mental powers. Usually it is taken by snuffing the powder. Some catarrh snuffs are said to contain it. These should be avoided since their use might lead to the formation of a habit.

Other Narcotic Drugs.—Some other narcotic drugs are made from coal tar. Among these are antipyrin and aspirin. They are all dangerous to heart action and should be avoided. Often they

Underwood and Underwood.

A National Peril

What was supposed to be a barrel of fish, when smashed by accident, proved to contain $750,000 worth of morphine smuggled into our country.

are the effective ingredients of "headache powders," remedies which should never be used without first consulting a physician.

It should be kept in mind that some so-called patent medicines contain a small per cent of a habit-forming drug. Remedies advertised to cure catarrh and other diseases often depend for their effect upon the presence of an opiate that may, if taken regularly, lead to the formation of a drug habit.

The *Pure Food and Drugs Act,* which was passed by the Fifty-ninth Congress of the United States in 1906, requires that every manufacturer of food or medicine label his products, stating the exact percentage of each ingredient. All manufacturers of patent medicines must conform to this law. Therefore no dangerous drug need be used without the user's knowledge. Always be sure what you are taking.

Alcohol.—Alcohol in all its forms is not merely a stimulant, but it belongs to the class of narcotics as well, for when taken into the body in large amounts it produces insensibility; and it is coming to be quite generally recognized that, even in small amounts, it tends to dull the senses and thus greatly diminishes efficiency.

The Relation of Alcohol to Business.—More and more, employers of labor are coming to recognize that men who use alcoholic drinks are not as reliable and in the end do not accomplish as much work as those who abstain from these drinks. There are many illustrations that prove this statement.

One of the rules of the New York Central and Hudson River Railroad forbids the use of alcoholic drink in the following words: "The use of intoxicating drink on the road or about the premises of the corporation is strictly forbidden. No one will be employed or continued in employment who is known to be in the habit of drinking intoxicating liquor."

The president of the Gulf States Steel Company writes: "Our record with the accident insurance companies is so extremely good that it has been frequently commented upon, and our staff is disposed to regard the low accident rate as measurably due to our freedom from drunken and tipsy workmen.

"Looking at the matter from an entirely different angle, I may say that I am also vice-president of the Bessemer Coal, Iron and Land Company. Prohibition was voted in this county (Birming-

ham, Alabama), on the same day in October, 1907, that the height of a panic was arrived at by the suspension of a trust company and the adoption of clearing house regulations restricting all drawing on private accounts to $100 at any one time. This is a mining and manufacturing community, and more than half the blast furnaces in the district shut down, throwing thousands of miners out of work.

"The Bessemer Company had, for two or three years previous to the panic, been selling large numbers of lots to the miners on the installment plan, payments running over ten years. Notwithstanding the panic and the number of men out of employment, installment payments were better met under a condition of panic plus prohibition than they had been with high wages and full work plus liquor. This showed in a remarkable way the greater efficiency of sober men in the matter of wage earning.

"A real estate firm told me that their experience in collecting rents was similar: Namely, that under panic plus prohibition they collected their rents vastly better than under the condition of luxury plus liquor."

Dr. Alexander Fleisher, who has made a special study of this matter, says: "We have returns from the employers of 750,000 individuals; this is four per cent of those engaged in trade, transportation, and the mechanical and manufacturing industries of the United States. These employers forbid alcohol in their plants; in many instances its use is considered in the promotion and retention of employees; its use at any time is prohibited in such industries as transportation, and this practice is being followed by some industrial establishments.

"This analysis indicates that a number of employers are making up their minds on the use of alcohol by their employees. By whatever reasoning they are arriving at their conclusion—whether they feel it is in the interest of the public, of the employee, or of good business—they seem to be taking a stand against the man who uses alcohol. They are not considering the intricate questions of the effects of alcohol on the mind and body—these preliminaries have been ignored; they find the non-drinker the more satisfactory employee."

The Evidence of Insurance Companies.—It has long been the custom of insurance companies to take into consideration every possible element that tends to shorten the lives of individuals. Accordingly, they have had special statistics prepared to show the effect of alcoholic drink on the length of life of the habitual user. These statistics, when compared with statistics giving the average length of life of abstainers from the use of these drinks, invariably show that the latter are longer-lived than the former.

In summarizing his studies of the whole field of American insurance statistics, the president of the New York Life Insurance Company said: "The opinions of the medical directors show that the life insurance companies look with disfavor on applications from persons who drink freely, although not to the point of intoxication, and on those who have taken alcoholic beverages to excess in the past but are temperate now. The statistics prove conclusively that this attitude of mind is based on facts, and that a higher mortality must be expected in these types of users of alcoholic beverages. On the other hand, it is conclusively proved that total abstainers are longer-lived than non-abstainers, even excluding from the latter those who drank immoderately at the date of application for insurance or prior to that time. The experience of seven American life insurance companies has proved that abstainers have from 10 per cent to 30 per cent lower mortality than non-abstainers; and there is no good reason for believing that, if the other companies compiled their statistics, there would be any different result, provided the companies exercised the same care in accepting abstainers and non-abstainers. The American statistics, now published, corroborate the British data in indicating the unfavorable effect of alcohol on length of life and in showing that total abstinence decidedly increases length of life."

SUMMARY

Narcotics are substances that affect the nervous system in such a way as to lessen the degree of activity of the organs which it controls. Among the most common narcotics are tobacco, opium, cocaine, heroin, and alcohol.

Tobacco used in any form in early life tends to prevent normal development of the heart. In adults, if used excessively, it may produce a nervous condition known as "tobacco heart." It may cause irritation of the membranes of the throat and lungs.

Some remedies advertised to cure diseases depend to a greater or less extent for their supposedly beneficial qualities on the presence of an opiate. Their use may develop the drug habit. One purpose of the Pure Food and Drugs Act is to protect the public against the use of medicines containing habit-forming drugs.

Alcohol in all its forms belongs to the class of narcotics.

Employers of labor report that the use of alcoholic drinks tends to make workmen unreliable, and in the end diminishes their efficiency.

Fact and Thought Questions

1. What is a narcotic?
2. Name the most common narcotics.
3. State the effect of the use of tobacco on the heart of a boy.
4. Mention some effects of the use of tobacco on athletes.
5. Why is it hard to break the tobacco habit by gradually reducing the amount you smoke?
6. What is cocaine? State the danger of using this drug.
7. What is heroin? What are the dangers of its use?
8. Suggest ways of breaking a drug habit.
9. Give the main requirements of the Pure Food and Drugs Act.
10. How can you tell whether a manufactured medicine contains habit-forming drugs?
11. How have you relieved a headache without use of a narcotic drug?

Project

1. Make a list of narcotic substances that should be avoided, giving reasons.

Reference

The Next Generation .... *Jewett*

CHAPTER XXX

HOW ALCOHOL AFFECTS CELL LIFE

Few of us deliberately welcome a trouble-maker into our homes. Few care to work or play with a trouble-maker. Yet for ages man has permitted alcohol, one of the greatest of trouble-makers, to affect his life seriously.

Alcohol puts stumbling blocks in the way of our mental, physical, and moral health. Where foods strengthen, alcohol weakens. Where foods warm us, alcohol makes us more susceptible to cold. It dulls our brain when quick and clear thinking is necessary and takes skill and steadiness from our hands. It lessens endurance and shortens life. Just why this is true the study of the effects of alcohol on the body cells will make clear.

You have learned that all organs of the body are composed of tissues, that tissues are made up of cells, that cells are extremely small and delicate, and that they are the units of both structure and function. You know that cells are composed of protoplasm, and that this substance is the basis of life. Anything that causes cells to deteriorate or to perform their functions, or life processes, less perfectly, is necessarily detrimental to the tissues and organs of which they form a part. Do small amounts of alcohol affect these minute delicate cells? Does alcohol act as a poison?

Effect of Alcohol on Body Cells.—Since the organs of the body are composed of cells, the effect of alcohol on an organ would be the same as the effect of alcohol on a single cell. As the protoplasm of which all cells are composed is of the same composition and nature, it seems reasonable to expect that the effect of a poison on cells in a mass, that is, in tissues and organs, would be similar to that on a single cell. In many forms of life, cells are fewer in number than in the human body. In the simplest forms of life, one-celled organisms, all the vital functions or processes of life are performed by a single cell. One of these simple

forms, known as the amœba, has been carefully studied and the effect of alcoholic poison on its activity observed. In considering this organism, it should ever be kept in mind that it consists throughout of living protoplasm, the material of which every active cell in our bodies is composed.

An English physician, in experimenting with the amœba and other minute organisms, observed that contact with dilute solutions of alcohol produced unfavorable effects on their activity. When placed under the microscope and subjected to a one per cent solution of alcohol, the cells showed lack of sensation for several hours. With a two per cent solution the deadening influence was even more evident for every cell stiffened and some died. With a four per cent solution most of the cells tested died, and with a five per cent solution all cells died.

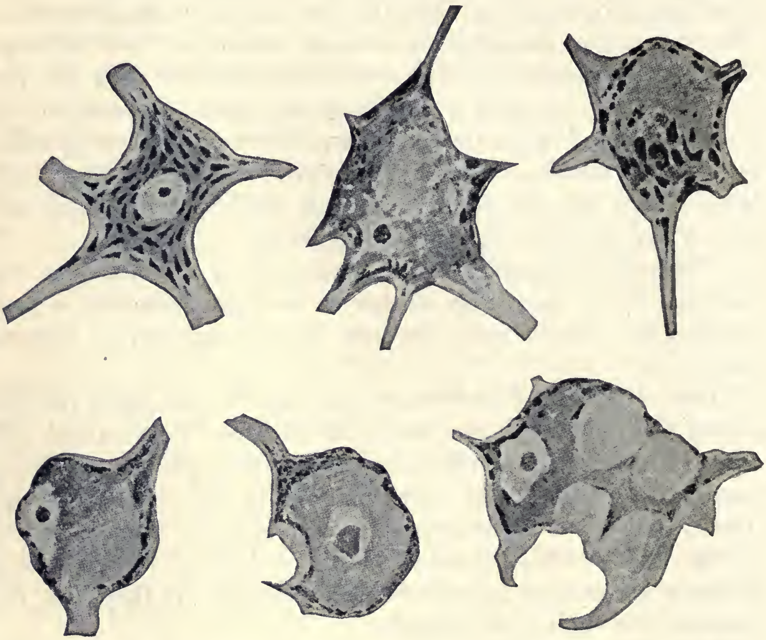
The white corpuscles in the human blood are quite like the amœba. They can readily change in shape and are able to pass through the tissues from one part of an organism to another part.

Prof. Metchnikoff of Pasteur Institute of Paris made the discovery that the white corpuscles of the blood are able to attack and overcome harmful bacteria and other minute organisms that may cause disease and death when present in the human system. There is often a battle between them and the disease germs, on the result of which depends the life or death of the individual. If the white corpuscles win, the life is saved. If they lose, the death of the individual follows.

Under the microscope it may be demonstrated that a small amount of alcohol taken into the blood affects live white corpuscles unfavorably. They are no longer able to exhibit the same activity as they did before contact with this stimulant. In the chronic alcoholic cases the microscope shows that the ability of the corpuscle to destroy disease germs is greatly lessened. Does not this account largely for the lowered vitality of persons who, to any extent, habitually use alcoholic drink? Experts say it does.

Why do insurance companies so carefully inquire into the drink habits of persons who wish to be insured, if not because they recognize that the man who takes poison into his system regularly

in the form of alcohol allows this enemy of the corpuscles, which protect him against disease, to enter his system and make its attacks? In critical cases of pneumonia or typhoid fever or other disease, physicians regard as favorable the fact that a patient has been an abstainer from the use of alcoholic drinks.



From "Alcohol and the Human Body."

EFFECT OF ALCOHOL ON BODY CELLS

The upper left hand cell is a normal healthy cell. The others are deteriorated cells taken from the spinal cords of habitual drinkers.

That the red corpuscles of the blood are also affected when they come into contact with alcohol has been proved. When it is recalled that the red corpuscles are the carriers of oxygen to the tissues upon which the production of energy depends, the harmful effect of alcohol in the blood will be readily understood.

The following, in regard to the effect of small doses of alcohol upon lower forms of animal life, is quoted from *Alcohol and the Human Body* by Horsley and Sturge:

"An English physician observed that a solution of alcohol, one part to one thousand, two thousand, or even three thousand parts of water, proved fatal to fresh water medusa, a kind of jelly fish.

"The details of his experiments were as follows:

"Water from the tank of the botanical gardens, in which this little fresh water jelly fish lived, was collected in a jar and charged with one gram of pure alcohol to a thousand of water. A duplicate jar of plain tank water was placed side by side with the first, as a check, or control. In each a medusa was placed.

"On entering the jar containing the alcohol and water the medusa's swimming movements were seventy-four to the minute, but within two minutes these stopped, and the animal began to shrink and to sink to the bottom of the vessel.

"At the end of five minutes the little creature lay at the bottom apparently dead and, although it was put into plain water for twenty-four hours, it did not recover. Meanwhile, the medusa in the other jar was active and unaffected.

"The experiments were repeated again and again, but they all resulted in proving that alcohol, even diluted to as little as one part of alcohol in a thousand parts of water, affected as a deadly poison the living protoplasm of these lower forms of life."

Physicians claim that certain foreign bodies have a detrimental effect on human protoplasm. Among these are toxins developed in such dangerous diseases as typhoid fever and diphtheria. It is a well-known fact that drugs like strychnine, cocaine, chloroform, and ether, if they gain entrance to the cells of the vital organs, also have a bad effect, for they too are protoplasmic poisons. It is gradually dawning on the minds of men that alcohol belongs to this class of drugs. Many people do not know that alcohol is placed by authorities on drugs in the list of narcotic poisons.

Effect of Alcohol on Plant Cells.—Dr. Hodge investigated the effect of alcohol on yeast cells. The result of his work was as follows: In the experiment with a yeast plant growing under natural conditions, in eleven hours 2061 cells developed. Adding a .001 per cent solution of alcohol, the number of cells developing under the same conditions was 1191. With a .01 per

cent solution the number developing lessened to 992 and with a 5 per cent solution only 69 cells developed. The lessening number must have been due to the action of the alcohol on the protoplasm of the yeast.

Experiments made with grain solutions containing yeast cells and alcohol also clearly show the effects of alcohol on cell life. It is an established fact that when the alcohol present in the solution reaches 13 per cent, the growth and multiplication of the cells cease, due to its presence. The alcohol evidently kills the protoplasm of the cells. More experiments as to the effect of alcohol on protoplasm might be referred to, but they all indicate that alcohol retards or stops cell development.

Some Other Facts About Alcohol.—The use of alcohol as a hardening and preserving agent is well known. If a piece of underdone meat or uncooked white of egg be placed in a mixture of equal parts of alcohol and water, the composition of ordinary brandy, hardening gradually occurs because alcohol absorbs the water from tissues.

It may be said that small amounts of any poison may be taken into the system with no bad results, and therefore that it can hardly be possible that the small amount of alcohol contained in beer can be injurious. If taken only occasionally this may be true. But if taken regularly it is not the case, since the effect of alcohol, like all poisons, is cumulative, and ultimately will prove injurious to cell life.

The great affinity, or liking, of alcohol for oxygen should be referred to. It is probably true that alcohol, once in the circulation, deprives the cells of oxygen intended to combine with food substances for the production of energy needed by the body. It also deprives them of the oxygen needed to oxidize poisons that accumulate, the excretion of which is absolutely necessary for good health.

Always keeping in mind the ability of alcohol to paralyze the actions of the white and the red blood corpuscles, to absorb moisture from the tissues of the body, and to take up oxygen needed for oxidation of food and of poisons that accumulate in the cells, you may be able better to understand the detrimental

effects of alcoholic drinks on the various tissues and organs of the body.

SUMMARY

In the simplest form of life, one-celled organisms, all the vital functions occur. Experiments show that a dilute solution of alcohol, when coming into contact with these organisms, decreases their activity and often kills them.

Experiments have shown that alcohol in dilute solution affects the blood corpuscles unfavorably, the same as it does an amœba, a one-celled animal. A similar effect is produced by alcohol on plant cells.

Alcohol absorbs water from living tissues, hardening them.

The effect of alcohol on the human system, if used regularly even in small amounts, is cumulative, like that of other poisons.

Alcohol, once in the circulation, deprives the cells of the oxygen which they need, and tends to paralyze the red and the white corpuscles of the blood.

Fact and Thought Questions

1. State the effect of alcohol on the white corpuscles of the blood.
2. What effect does alcohol have on yeast cells?
3. Why does a piece of partially cooked meat harden when placed in alcohol?
4. What reason is there to suppose that the effect of alcohol on an organ of the body is the same as on a single cell?
5. Why is the alcohol drinker more likely to suffer from exposure to cold than a man who does not drink?
6. Name three ways in which the use of alcohol keeps one from being physically fit.
7. Suggest how alcohol might prevent right action in an emergency.
8. Why are continued small doses of alcohol dangerous?

Projects

1. Pour a solution of alcohol into a small aquarium containing paramecia and observe the effect on the animals.
2. Describe experiments, about which you have read, that tell of the effects of alcoholic solutions on one-celled organisms.

Reference

Alcohol and the Human Body........................*Horsley and Sturge*

CHAPTER XXXI

HOW OUR BODIES DIGEST AND ABSORB FOOD

The fires in our house heaters will not provide the warmth we need if fuel is fed to them in wrong sizes or amounts, or if clinkers and ashes are permitted to collect. Our automobile motors will not run with crude oil fresh from the wells. This oil must first be refined and modified into energy-producing gasoline.

Similarly the food we eat must be changed to a form that will produce the energy we need. Fortunately our human machine, the body, is equipped with wonderful apparatus for this service. It takes our food fuel, transforms it to a liquid, changes its nature and sends the body-building and energy-producing elements through the blood to points of need. Wastes, it eliminates.

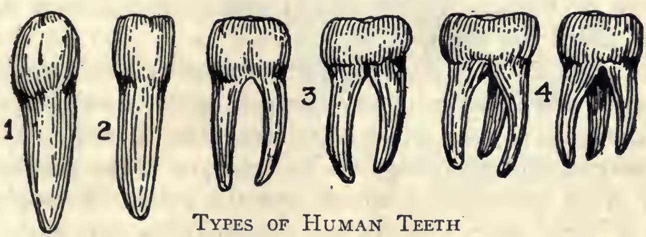
If we are healthy we let this apparatus labor along as it will. It has, however, many parts which get out of order if we misuse them, if we clog up the machinery, or if we give it too much work to do. That is why, for our own health and strength and comfort, we need to add to our scientific knowledge an understanding of this apparatus—our digestive system.

Digestion.—*Digestion* is the process by which the food we eat is so changed that the nutrient substances can be absorbed into the blood. Digestion is accomplished by reducing the food to a liquid and subjecting it to the action of chemical substances called *enzymes,* or ferments, secreted, or given off, by glands in the body. The nourishing parts of the food are then absorbed through the lining membrane of the digestive organs into the blood, a process called *osmosis.*

The organs of digestion form a continuous tube known as the *alimentary canal.* The most important parts of the alimentary canal are the *mouth,* the *pharynx,* the *esophagus,* or *gullet,* the *stomach,* the *small intestine* and the *large intestine.* The entire canal is nearly thirty feet long.

The Mouth.—The mouth takes in the food. It is provided with teeth, for use in chewing and preparing the food for digestion; with cheeks, which are muscular walls that allow the jaws room to move in chewing; with a wall or roof, formed by the hard, bony palate in front and the soft palate behind; with a tongue, a muscular organ that aids in moving the food in the mouth when chewing, and also causes the sensation of taste by means of minute projections, called *papillæ,* on its upper surface. The mouth also contains *salivary glands* that secrete *saliva* to moisten and help digest the food. The surface of all these parts, the teeth excepted, is composed of *mucous membrane.*

Teeth.—Nature provides each person who lives to adult age with two sets of teeth. The first is a set called milk teeth, twenty in number, ten in each jaw, which belongs to the earlier years of childhood. The second is a permanent set, which develops as soon

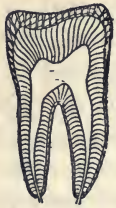


TYPES OF HUMAN TEETH

1. An incisor, or cutting tooth.
2. A canine, or tearing tooth.
3 and 4. Molars, or crushing teeth.

as the milk teeth are lost. There are thirty-two teeth in the permanent set, sixteen in each jaw. Each half-jaw has eight teeth of similar shape and arranged in the same order, as follows: two *incisors,* well adapted for cutting by their sharp, chisel-like edges; one *cuspid,* sometimes called canine, adapted for tearing by its sharp-pointed structure; two *bicuspids,* adapted for crushing and grinding food by their blunt crowns; and three *molars,* especially adapted for crushing and grinding food by their broad, rough, uneven surfaces. The third molar in each half-jaw is called the wisdom tooth. It develops late and is often not as strong and useful as the other teeth.

Each tooth consists of three parts. The *crown,* covered with hard white enamel, is the visible part of the tooth, above the gum. The tooth extends through the gum and is rooted in the jaw. The part of the tooth encased in the gum is called the *neck.* The third part, the *root,* is surrounded by a bony substance called cement, and is imbedded in the jawbone. The tooth is composed largely of an ivory-like material called *dentine.* The interior is filled with a substance called *pulp,* which contains the nerves and blood vessels that enter it through small holes at the ends of the roots.



CROSS SECTION OF A TOOTH
Showing the enamel, dentine and pulp.

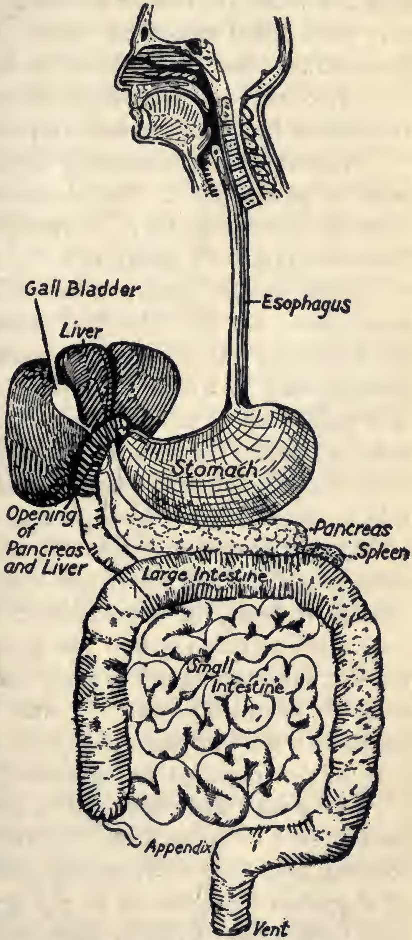
Salivary Glands.—There are three pairs of salivary glands: the *sublingual,* lying under the sides of the tongue; the *submaxillary,* lying just beneath the angles of the lower jaw at each side, and the *parotid,* lying in the cheeks just in front of the ears. The parotid glands are the seat of the disease called the mumps.

These glands secrete saliva, which moistens all food taken into the mouth, and by means of an enzyme or digestive ferment, called *ptyalin,* digests to some extent the starchy part of food.

Pharynx and Esophagus.—The pharynx is the pear-shaped cavity lying between the mouth and the gullet, or esophagus. It is a little over four inches in length in an adult. Its walls have seven openings into other parts of the body. The two that concern digestion open into the mouth and the esophagus. Of the other five, one opens into each nostril, one into each ear, and one into the trachea, or windpipe. This last opening has a movable cover which closes when swallowing occurs, to keep food out of the windpipe. A person would choke if food slipped into the trachea. Just in front of the pharynx on each side there is a fleshy tissue called the *tonsil.*

The esophagus, the next part of the alimentary canal, leads to the stomach. The esophagus is open only during the passage of food. When not filled out by food as it is forced downward, the esophagus lies flat, its walls pressed or crumpled together.

The walls of the esophagus, like those of the entire canal, consist partly of muscular fibers so constructed as to force the food downward. The outer wall is composed of longitudinal muscles, the inner, of circular muscles. These sets of muscles contract, or grow shorter, and expand, or stretch, alternately, squeezing the food always towards the lower end of the canal. This action, known as *peristalsis,* takes place throughout the alimentary canal, from the time the food leaves the mouth. The act of swallowing sets the muscles in motion and the peristalsis is continued all the way down the canal. Peristalsis in the esophagus forces the food into the stomach.



THE ALIMENTARY CANAL

The Stomach.—The stomach is a very important organ of digestion. It is a pear-shaped pouch, having a normal capacity in an adult of about three to five pints. It has two openings. The one by which the food enters from the esophagus is called the *cardiac* opening. The other, through which the food passes into the small intestine, is called the *pylorus.* In an adult the stomach is from ten to twelve inches in length and about five inches in diameter, and its walls are not over one-eighth of an inch in thickness. The walls are made up of several coats, or layers. The outer surface is covered with a thin, shiny membrane

called the *peritoneum,* and the inner surface is lined, like the other parts of the canal, with mucous membrane.

Glands of the Stomach.—In the mucous membrane of the stomach there are numerous minute glands which secrete a digestive fluid called the *gastric juice.* The gastric juice is made from material supplied by the blood in the capillaries of the membrane. This juice is a yellowish fluid, composed largely of water, holding in solution hydrochloric acid and two ferments, *rennin* and *pepsin.*

Peristalsis in the stomach helps to mix the food thoroughly with the gastric juice. This action is sometimes called the churning motion of the stomach. Normally about three quarts of gastric juice are produced daily.

Work of the Gastric Juice.—The gastric juice is of prime importance, for it is the first main factor in making the protein food soluble. It contains ferments, or enzymes, which change protein food to a soluble form. This is effected by the pepsin and hydrochloric acid in the juice. Pepsin acts only in an acid solution; hence the importance of the hydrochloric acid. The acid also renders soluble, or digests, mineral matter in the food and is said to destroy many bacteria and prevent fermentation.

Rennin, the other ingredient of gastric juice, curdles the proteins in milk so that the pepsin can change them to soluble forms. Rennin is especially important in aiding digestion in children as they drink so much milk. The gastric juice does not digest starch and fat, but makes protein food soluble. The food as it leaves the stomach is called *chyme.* A little of it is absorbed through the stomach walls but most passes on into the small intestine, where it is further digested and absorbed.

The Small Intestine.—The small intestine consists of a tube twenty feet or more long, covered, like the stomach, with peritoneum, and lined with mucous membrane. The important work of digestion that goes on in this organ is the mixing of the food with three kinds of fluids, *pancreatic juice, bile* and *intestinal juice.* The pancreatic juice and the bile are made in two large glands which are just outside the small intestine, and are poured into the intestine through small openings. These glands pour their secretions into the small intestine in a way similar to that of the

salivary glands. The intestinal juice is made in the intestinal glands, which are in the walls of the small intestine.

The first of the large glands mentioned is the *pancreas,* a wedge-shaped organ about six inches long and one inch wide. It lies behind the stomach and secretes the pancreatic juice.

The *liver,* the second gland, is the largest in the body. It is a dark-red mass, lying on the right side of the body under the lowest ribs, and consists of several lobes. It secretes a yellowish fluid, called *bile,* and is connected with a bag-like organ, called the *gall bladder,* which stores the bile. The liver changes sugar, which it absorbs from the blood, into a form of grape sugar called *glycogen,* and stores it for use in supplying energy for the contraction of body muscles. The liver also acts as an excretory organ by throwing off poisonous substances with the bile.

The Pancreatic Juice.—The pancreatic juice contains three ferments or enzymes which do a great deal toward making the food soluble. Its ferments are *trypsin,* which acts on undigested albumin; *amylopsin,* which acts upon starch; and *steapsin,* which acts upon fat. In these processes the partly digested food is changed into an alkaline condition.

Bile and Intestinal Juice.—The bile and the intestinal juice meet the chyme, or food sent from the stomach into the small intestine, and act upon it. Peristaltic action here helps to mix the food and the juices.

The most important use of the bile is in breaking up fats so that the steapsin may act more readily upon them. The intestinal juice neutralizes the acids that form as a result of chemical changes in the intestine, and aids a little in digestion.

After the action of these three fluids, the food is called *chyle,* instead of chyme, and is now in soluble form, ready to be absorbed through the mucous membrane of the alimentary canal and the capillary walls into the blood, which carries it to the cells.

The Large Intestine.—The large intestine, the last part of the alimentary canal, is a tube five or six feet in length whose chief function is the removal of waste material from the body. One region of this canal has a worm-like extension, known as the *vermiform appendix,* which is the seat of the disease called appen-

dicitis. There are no digestive ferments secreted by the glands of the large intestine; therefore if any digestion occurs, it is due to secretions that pass into it from the small intestine. It is often a breeding place for bacteria that induce fermentation and become a source of danger to the health.

Absorption.—When food has been thoroughly digested and is in soluble form, it is ready to pass through the mucous membranes of the alimentary canal into the blood. The process of this movement of the digested food into the blood is known as *absorption.*

Absorption begins in the stomach and is continued in the small intestine. Since only digested food can be absorbed, the amount taken up in the stomach is slight, as only a small portion of food is completely digested there. By far the greater part of absorption takes place in the small intestine.

VILLI OF THE SMALL INTESTINE

The small intestine is well adapted by structure for the absorption of food. It is very long and coiled and its inner lining is covered with numerous small projections, called *villi,* thus affording a large surface for absorption. These villi, found in no other part of the alimentary canal, contain two kinds of capillaries, *blood* capillaries and *lacteals* or *lymph* capillaries, all tiny tubes which convey the fluid food to the blood by two distinct routes.

Let us first consider the route through the blood capillaries. They carry all non-fatty food, which is absorbed by the process of osmosis from the small intestine through the walls of the villi, and through the walls of the blood capillaries. These many and intricate blood capillaries merge into one tube, called the *portal vein.* The fluid enters this vein, and is carried to the liver where it undergoes certain changes.

The fats reach the blood by a different course. They, too, are absorbed in liquid form by the process of osmosis, through the cell walls of the villi. Here they enter the lacteals, which merge into a tube called the *thoracic duct.* This tube carries the fluid fatty food to a large vein at the base of the neck into which it opens and discharges its contents into the blood current.

Some Experiments Related to Digestion.—

Study of the Mouth Cavity.—Study your own mouth, observing the position and number of the different kinds of teeth; the composition of the walls of the mouth, bone and muscle; the position of the hard palate, the soft palate and the tonsils; the shape, structure and attachment of the tongue; and the size and location of the opening into the throat.

To Determine the Uses of the Teeth, Tongue and Cheeks in Eating.—This knowledge should be gained from the study of your own use of these organs.

Digestion and Absorption

Digestive Fluid	*Organ of Secretion*	*Enzyme or Digestive Ferment*	*Effect of Digestive Fluid on Food*	*Absorption*
Saliva	Salivary glands, emptying into the mouth	Ptyalin	Changes starch to sugar	
Gastric juice holding in solution pepsin, rennin and a small percentage of hydrochloric acid	Gastric glands, emptying into the stomach	Pepsin Rennin	Changes protein to soluble form. Makes mineral matter soluble	Small amount of absorption by capillaries in walls of stomach
Pancreatic juice	Pancreas, emptying into the small intestine	Trypsin	Changes albumin to soluble form	Large amount of absorption by capillaries of villi in small intestine
		Amylopsin	Changes starch to sugar	
		Steapsin	Changes fats to a form easy to absorb	Large amount of absorption by lacteals of villi in small intestine
Intestinal juice	Intestinal glands, emptying into small intestine	Invertin	Neutralizes acids and aids in digestion	Absorbed by capillaries of villi in small intestine
Bile	Liver, emptying into small intestine	....	Breaks up fats	Absorbed by lacteals of villi in small intestine

To Show the Digestion of Starch.—Prepare starch paste by mixing a teaspoonful of starch in a gill of water. Place some of the starch paste in each of two test tubes. To one of the test

tubes add saliva and shake the contents. Place both test tubes in a pan of water at 98.5° Fahrenheit for ten or twelve minutes. Remove both tubes from the water, add Fehling's solution to each tube, and then heat. Observe results.

To Show the Digestion of Protein.—Place a small piece of the white part of a boiled egg in a test tube containing a solution of pancreatin or pepsin and close the open end of the tube with absorbent cotton. After shaking, leave the tube with its contents for a few hours in a room at about normal body temperature. For a control, prepare a second tube in the same manner, using water instead of a solution of pancreatin or pepsin, and set it aside under the same conditions and for the same length of time as the first tube.

Observe that the piece of protein in the first tube has disappeared. It has dissolved, that is, has been digested. Why did the piece in the second tube not dissolve?

To Show the Digestion of Fat.—Place a small amount of olive oil in a test tube containing a solution of pancreatin and close the open end of the tube with absorbent cotton. After shaking the tube with its contents thoroughly, set it aside for a short time. For a control, prepare a second tube in the same manner, using water instead of a solution of pancreatin. After shaking, set it aside with the first tube.

Observe that in the first tube an emulsion has been formed, that is, the fat particles have been separated and the contents have a milk-like appearance. A similar effect is produced by digestive fluids on fatty food in the intestine, rendering it soluble. Observe what happened in the second tube and account for the different result.

SUMMARY

Digestion is the process by which the food we eat is so changed that the nutrient substances can be absorbed into the blood.

The most important parts of the alimentary canal are the mouth, the pharynx, the esophagus, the stomach, the small intestine, and the large intestine.

The mouth is the cavity where the food is chewed by the teeth, mixed with saliva and reduced to a pasty mass. The saliva changes some of the starchy food to sugar.

From the mouth the food passes through the pharynx and the esophagus into the stomach.

The stomach is a muscular bag covered with a thin, shiny membrane, called the peritoneum, and lined with a soft, moist substance, called the mucous membrane, in which are glands that secrete gastric juice.

The gastric juice partially digests the protein food. It has no action upon starchy and fatty foods.

In the small intestine food is further digested by the pancreatic juice, aided by the action of the bile and the intestinal juice.

The large intestine performs the last part of the digestive process, the excretion of waste material. It is often a breeding place for bacteria.

Absorption is carried on by osmosis—the passage of a liquid through a membrane. It begins in the stomach, but is largely accomplished in the small intestine.

Fact and Thought Questions

1. Name the parts of the alimentary canal.
2. Describe the structure of the stomach.
3. How is the small intestine equipped to perform its work?
4. Give the function of the gastric juice; of the saliva.
5. Name the kinds of teeth.
6. Give the number and the location of each kind of teeth in an adult.
7. Describe the structural adaptations of each kind of teeth.
8. Describe an experiment to show digestion.
9. From what part of the alimentary canal is most of the digested food absorbed?
10. Tell how peristalsis takes place in the alimentary canal and what effect it has on digestion.
11. Why does the taste of the food we place in our mouths change, or even disappear, as we chew?
12. Through how many "doorways" does food pass from mouth to intestines?
13. Name some article of food you ate for breakfast and tell what the body had to do to it to benefit from it.

14. Complete these statements:
    (a) Food is absorbed by the ———— in the small intestine.
    (b) ———— is digested in the stomach.
    (c) Starch is digested in the ————.

Projects

1. Observe the digestive organs of a dissected frog, or carefully study a chart showing these organs.
2. Observe different kinds of teeth to discover their adaptations.

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CHAPTER XXXII

DIGESTION AND HEALTH

If cared for and properly used, most modern machinery lasts a long time. But carelessness, overtaxing, or unskilled running shortens its life and may wreck it.

One who knows simply how a machine is constructed and how it works is not an engineer. The skilled engineer draws the most energy from his engine with the least strain. He demands no more of it than it is fitted to give and he knows how to handle it to meet different conditions.

We are the engineers of our bodily machinery. Each part of this intricate machine of ours is intended to have a long life, if properly used. It is not enough for us simply to know how a part works. We must learn how to care for it and how to run it without strain or abuse so that it may produce the energy we need. Why not be better engineers of our human machine?

Habits Affecting Digestion.—It is true that much discomfort is caused by improper methods of eating, and that the observance of a few simple rules would help people to avoid some of the ills that they suffer. Since the food, once swallowed, is practically beyond control, it would seem wise to give due attention to those habits in regard to digestion that we can easily modify. Among these habits are intemperate eating, insufficient chewing of the food, eating between meals, lack of a properly rested body and a cheerful state of mind at meal time, violent exercise or hard study just after eating, lack of proper care of the mouth and teeth and of due attention to regularity of excretion of waste from the intestines.

Intemperate Eating.—It does not always occur to people that there can be intemperance in eating as well as in drinking. The habit of overeating is harmful. Some of the food fails to digest and *toxins,* or poisons, are formed in the intestine, which, when absorbed, affect the nervous system unfavorably. People

who "live to eat" are sure, sooner or later, to pay for this pleasure with some form of discomfort or disease.

Too large a quantity of food eaten at a single meal stretches the stomach and hinders the peristaltic, or wave-like, movements of the muscles within its walls, which force the food along into the intestine. Food thus delayed is apt to ferment, causing headache, palpitation of the heart and other unpleasant sensations. The food may also sour and generate gases which are sometimes gulped up and thrown off through the mouth, indicating indigestion. This condition is likely to produce serious stomach trouble.

Insufficient Chewing.—When food is not chewed sufficiently the saliva fails to become thoroughly mixed with it, and consequently does not perform its work well. Moreover, the supply of saliva is inadequate since the process of chewing is necessary to stimulate its flow from the glands in the mouth. As the saliva continues to assist in changing starch to sugar after the food enters the stomach, and also aids the flow of gastric juice necessary for the digestion of protein, the need of sufficient chewing is apparent. Eating between meals and having meals at irregular hours tend to increase the bad results of insufficient chewing, as the digestive glands are more or less influenced in their activity by habit. Every one should form the habit early in life of eating slowly and chewing food until it is thoroughly broken up and reduced to a pulpy mass.

Relation of Rest to Digestion.—When the body is weary or the brain is worried by business or other cares, the digestive glands do not respond as they should to the stimulus of food. So, when tired from overwork or for any reason disturbed in mind, a quiet resting time should precede eating. For the sake of good health, a rested body and a calm and happy frame of mind are always desirable at mealtime. Rest is also needed immediately after a meal, as the stomach requires an extra quantity of blood to perform its function well. Violent exercise and close application to study should not immediately follow a full meal. Some light form of diversion, like story telling or games that demand only slight effort, is favorable to the digestive process.

Mouth Hygiene.—The first part of the alimentary canal, the mouth, should always be kept in a clean and healthy condition. Otherwise germs of disease find there a fertile place for growth and reproduction. Mouth hygiene centers largely around the teeth. Tooth decay is a source of much discomfort and should be prevented.

This can be done by proper care of the teeth. Particles of food should never be left between the teeth, since they provide a breeding place for bacteria. These bacteria secrete an acid which dissolves the enamel, or hard outer covering, of a tooth and then attacks the dentine, or softer part beneath, causing rapid decay. The decay, making a cavity, soon reaches the nerves of the tooth and causes toothache.

Tooth decay is also one of the most common causes of indigestion. This will be apparent to any person who recognizes the close relation between digestion and the production of energy necessary to carry on life processes and to perform one's daily work. Poor teeth mean that food is not well prepared for digestion in the stomach and intestines. Therefore it is not fully absorbed into the blood and of course fails to do its part in the production of energy.

A disease called *pyorrhea,* or Rigg's disease, also affects the teeth, causing them to loosen and finally to come out of their sockets. Pyorrhea is supposed to be the result of an infection of the gums. It begins near the edges of the gums where the membrane has been slightly broken, gradually extending to the parts that attach the root of the tooth to its socket, destroying them and loosening the tooth. This disease is said to cause greater loss of teeth than decay.

Many bad results follow neglect to care for the teeth. Not only toothache and indigestion but also neuralgia, a very painful disease of the nerves of the face, often occur when no effort is made to check decay. Moreover, recent investigations have shown that the bacteria, or germs, that cause decay may generate poisons that affect the whole system unfavorably. It is said that the germs, after getting into the tissues around the teeth, work their way into the circulation and are carried by the blood to the various

organs of the body where they cause rheumatism and other serious forms of disease.

Decayed places in the teeth should be filled by a dentist as soon as discovered. Tartar should not be allowed to gather on the teeth, as it is likely to injure the enamel and the gums, thus enabling germs of disease to infect both the teeth and the tissues. There should be regular visits, at least twice a year, to the dentist to have the teeth examined and cared for. Teeth should be brushed after each meal and before retiring. Particles of food should be removed with dental floss, and the mouth should be rinsed daily with an alkaline solution, such as common baking soda.

In childhood and early youth the teeth should receive expert attention. Many states, recognizing this fact, now provide free dental inspection for the pupils of their public schools, and some have school dental dispensaries in operation.

Excretion of Waste Matter.—The importance of the final act of digestion, the excretion of waste matter from the intestines, cannot be over-emphasized. The retention of this waste is a great menace to health as it contains the poisons resulting from the decomposition of undigested food and from the material thrown off by the liver and other glands into the intestines. When not gotten rid of, these poisons are taken into the blood, circulated through the body and absorbed by the cells of the tissues, causing headache, loss of appetite, indigestion and other disorders.

Constipation.—The lack of adequate movement of the bowels is called *constipation.* It may result from a number of causes, among which are improper diet, failure to drink enough water, insufficient exercise, improper posture in sitting and irregular habits. The best way to cure constipation is to remove the cause. A diet made up largely of coarse foods, such as corn bread, fruits and various kinds of green vegetables, helps to bring relief. They contain considerable woody material, or cellulose, which, by its bulk, aids in stimulating the peristaltic movement of the digestive tube. Relief may often result from increasing the daily quantity of water taken. The belief, formerly popular, that water should not be taken with the meals no longer prevails. According to recent

investigations it may be used quite freely during meals without harm, provided it is not used to wash down food and thus retard the action of saliva. A large glass of water taken just before going to bed and another before breakfast in the morning will often aid in the prevention of constipation.

Effect of Alcohol on the Mouth, the Stomach and the Liver.—The whole alimentary canal has a lining of mucous membrane. This membrane is an internal skin, far more sensitive to contact with objects than the external skin. You may easily convince yourself of this by applying an irritant to your skin and at the same time applying it to the mucous membrane by placing a small amount in your mouth. In the latter case, it will produce a painful sensation owing to its contact with the delicate protoplasm of the cells that compose the mucous membrane.

Alcohol is an irritant and affects the mucous membrane of the mouth in a way similar to that of the irritating substance placed on the tongue. It affects the protoplasm of the cells, absorbs the moisture and, if its use becomes habitual, it causes the cells to shrink. It irritates the mucous membrane in the stomach and injures its delicate structure, thus interfering with the normal digestive process. It lessens the peristalsis of the stomach and hinders the digestive action of the pepsin.

Experiments that have been made on the amœba and other forms of single-cell life show that alcohol is injurious to them. Since the mucous membrane is composed of large numbers of minute cells, each of which has the same composition, structure and functions as an amœba, it seems reasonable to conclude that alcohol has a similar effect on these cells massed in tissue that it has on a single cell. Nor does the fact that only a small amount of the drug reaches them affect the force of the argument, since the effect of alcohol, like that of other drugs, is cumulative.

The liver, like other organs, is composed of a vast number of cells. If the contact of alcoholic poison with the liver continues long enough, it may destroy the usefulness of the cells, and cause hardening of the tissues.

SUMMARY

Harmful effects often follow overeating. Toxins are apt to form in the undigested food which may be absorbed into the system and affect it unfavorably.

Insufficient chewing prevents the thorough mixture of the food with saliva, and eating at irregular hours tends to produce the same result. Eating when fatigued and working vigorously immediately after a meal hinder digestion. Rest is desirable.

The care of the teeth should not be neglected. Decayed places should be filled by a dentist. Tartar should not be allowed to remain on the teeth.

Attention to excretion of waste from the intestines should never be neglected. Constipation may lead to other serious disorders.

Alcohol irritates the cells of the mouth and stomach and absorbs the moisture from the tissues. It delays the digestive process in the stomach and injures the cells of the liver.

Fact and Thought Questions

1. Mention bad effects of overeating.
2. Discuss the relation of rest to digestion.
3. What bad results follow neglect of the care of the teeth?
4. Why is the excretion of waste matter necessary?
5. Mention some causes of constipation.
6. State the effect of alcoholic drink on the mucous membrane of the mouth.
7. Is it wise to eat a hearty meal immediately before a difficult examination?
8. Why shouldn't we eat the food we need in six meals a day rather than three?
9. Which part of the process of digestion is entirely under our control?
10. What habits of eating may "destroy" our appetite?
11. Suggest some rules to observe for eating immediately after a severe illness.
12. If we chew starchy food, why do we get a sweet taste?
13. Why should we not exercise vigorously after eating?

Projects

1. Examine your teeth to ascertain whether they are in normal condition.
2. Observe your habits of eating, and decide whether or not they are right.

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CHAPTER XXXIII

CIRCULATION, ASSIMILATION AND EXCRETION

It would do us little good to provide our bodies with the proper food and to digest that food if there were no system for carrying the nourishment, and the oxygen necessary to burn it, to the cells where they are needed.

To meet this need, our wonderful human machine is provided with a force pump that sends a stream of blood to all the parts of our bodies. This blood picks up the digested food and oxygen and distributes them to the cells to repair waste and produce energy. Having done this, the blood gathers up and carries away waste and worn out material to points of discharge from the body.

The circulatory system is always working to free the body of what endangers it, and to meet special needs. So the heart pump speeds up when exercise demands more energy and therefore more oxygen. It slows down when the need is past. The whole system is a wonderful illustration of making every move count for something worth while. We should know more about its structure and use in order to help and not to abuse it.

Circulation.—The circulatory system consists of the heart and of a complicated arrangement of tubes called *arteries, veins* and *capillaries* through which the blood is constantly moving. The blood carries food and oxygen to all the cells of the body, and carries away the carbon dioxide, urea and other wastes excreted by the cells. The heart furnishes the power which causes the blood to move through the arteries to all parts of the body and to return through the veins after passing through the capillaries, which are small connecting tubes that unite the arteries with the veins.

The Blood.—The blood is a red liquid forming about eight per cent of the weight of the body. It is composed of red and of white corpuscles floating in a colorless liquid called plasma.

The plasma is about ninety per cent water and holds in solution organic and mineral matter which form most of the other ten per cent. The organic and the mineral matter are the nutrients of the cells. Waste matter from cells is constantly thrown into the plasma and is carried away by it.

Red Corpuscles.—The red corpuscles are flat circular plates with rounded edges and a depression in the center of each. They are cells without a nucleus, microscopic in size and countless in number. When seen in mass they have a bright red color. They make up nearly one-half the weight of the blood and are composed of an albuminous substance, mainly hemoglobin. They carry oxygen. The red blood corpuscles are formed in the marrow of the bones and in a small organ called the *spleen.*

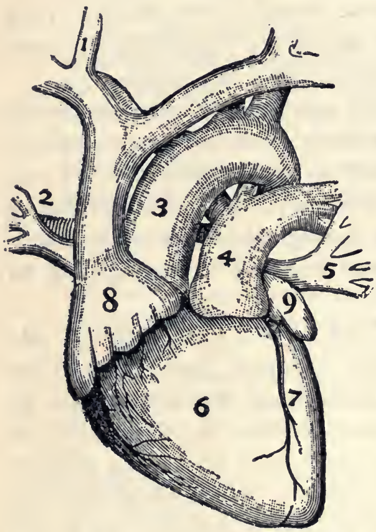
White Corpuscles.—The white corpuscles are irregularly shaped, colorless cells having a nucleus. They are microscopic in size and are about one five-hundredth as numerous as the red corpuscles. They are able to change their shape and to wander among the cells of the body, even passing through the walls of the capillaries. They destroy disease germs and aid in the healing of wounds.

Changes in the Composition of the Blood.—The chemical substances of the blood are constantly changing their proportions as it passes through the body. In the lungs the blood takes up oxygen and excretes carbon dioxide. In the muscles and other tissues it gives off food and oxygen and takes up carbon dioxide, urea and other wastes. In the walls of the alimentary canal digested food is taken up and wastes are given off. As it circulates, the blood gives out the material needed by the cells for growth and repair and for making of digestive fluids. In the kidneys and skin, the blood gives off oxygen and nutritive material and gets rid of water and a nitrogenous waste called urea.

Clotting of Blood.—When blood flows from the body, as from a cut, it forms a jelly-like substance and is said to coagulate, or clot, separating into two parts. The liquid part of clotted blood is called *serum,* which consists of water with organic and mineral matter in solution. The solid portion, called *fibrin,* holds the corpuscles in its meshes.

Clotting is of importance in stopping the flow of blood from a wound. Sometimes, in disease or sickness, a clot forms in the body with unfavorable results.

Blood Temperature.—The normal temperature of the human blood is about ninety-eight and six-tenths degrees Fahrenheit. Under ordinary circumstances it varies little if at all. Any considerable rise above or drop below the normal is an indication of serious illness. Man and other mammals and birds are warm-blooded and as such are not able to adapt themselves readily to extreme ranges of temperature. In this respect they differ from cold-blooded animals, such as frogs, fish and snakes, whose blood has no fixed temperature but may vary by several degrees with the temperature of the medium in which they live.



THE HEART—A WONDERFUL FORCE PUMP

1. Artery to the Head.
2. Right Bronchial Tube.
3. Aorta.
4. Pulmonary Artery.
5. Left Bronchial Tube.
6. Right Ventricle.
7. Left Ventricle.
8. Right Auricle.
9. Left Auricle.

The Heart.—The heart is a hollow muscular organ, conical in shape, and, in an adult, about the size of the fist. It lies in the breast, its side resting upon the diaphragm. It is enclosed in a membrane called the *pericardium.* Its front surface is nearly covered with the lungs. It consists of four chambers, two upper chambers called *auricles,* and two lower chambers called *ventricles.*

The work is done largely by the ventricles, which have thick muscular walls. The left ventricle, which has the stronger muscle, forces the blood through the greater part of the body. The right ventricle forces the blood through the lungs.

Pumping Action of the Heart.—The heart may be compared to a double pump with the strong muscles in the ventricles supplying

the force. Like a pump, the heart has valves—*mitral* valves, *tricuspid* valves and *semilunar* valves. These valves are thin, strong doors between the auricles and ventricles. They readily open to allow the passage of blood forward, but immediately close after the blood passes, and are held down tightly by its backward pressure, so that it does not return but flows onward. When the mitral valve, which is composed of two flaps, opens, the blood flows from the left auricle to the left ventricle. When the tricuspid valve, which is composed of three flaps, opens, the blood flows from the right auricle into the right ventricle. Other valves are found at the openings of the arteries leading from the ventricles. They are made up of three flaps and on account of the resemblance of each flap to a half-moon they are called *semilunar* valves.

The Arteries.—The vessels in which the blood flows from the heart to the various organs of the body are called arteries. Arteries are well adapted by structure to do their work. They are pipe-like in their make-up and are covered with a layer of connective tissue that protects the inner lining which is composed of cells. They are elastic and for the most part do not lie near the surface of the body.

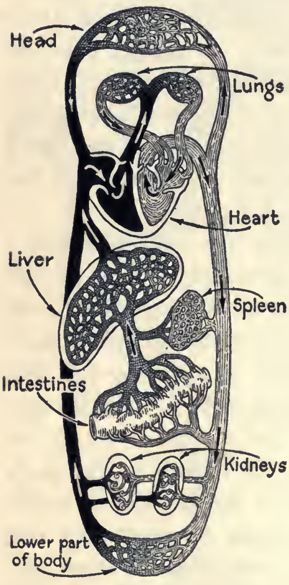
The Pulse.—The blood flows through the arteries with a wave-like motion. This motion causes a throb which may be felt wherever an artery passes near the surface of the body, as in the wrist. This throb is called the *pulse*. The number of heart beats per minute may be determined by counting the throbs for that length of time. In an adult the normal pulse varies from seventy to eighty throbs per minute.

The Veins.—The blood returns from the organs of the body to the heart through a series of pipe-like vessels called veins, formed by the coming together of a network of capillaries that originates at the ends of the arteries. The veins have thinner and less strong walls than the arteries and the blood current moves more slowly. They have valves at intervals which prevent a backward flow but do not hinder the onward course of the blood to the heart.

The Capillaries.—The capillaries are extensions of the arteries that develop from the lining of the arteries and lead to

the veins. They are very numerous and exceedingly small tubes and, as has already been stated, form the connecting link between the arteries and the veins. They penetrate all the spaces between the cells of the body, forming a network that surrounds them. Blood plasma, containing food and oxygen, diffuses by osmosis from the walls of the capillaries into these spaces. Wastes from the cells also gather in these spaces. The mixture thus formed is called lymph and the spaces are called lymph spaces. From this fluid the cells absorb their food and oxygen.

The capillaries not only bring the food and oxygen, but they also take up and remove some of the wastes that are in solution. They are well adapted for their work by the exceedingly thin tissue of their walls. The food and oxygen pass into the lymph, thence into the cells by the process of osmosis, and the wastes pass out of the cells into the lymph, thence into the capillaries by the same process. The wastes flow on in the larger blood vessels by which they are carried to the organs of excretion, where they are eliminated.



CIRCULATION OF THE BLOOD
Trace its course.

Course of the Circulation of the Blood.—Starting in the left ventricle the blood in a *complete circuit* takes the following course: left ventricle, through the left semilunar valve into the *aorta,* the great artery leading from the heart, from which it is distributed by arteries to all parts of the body. It then passes through the capillaries into the veins and on to the right auricle of the heart. From the right auricle it passes through the tricuspid valve to the right ventricle, then through the pulmonary artery into the capillaries of the lungs, from which it passes through the pulmonary veins to the left

auricle of the heart and through the mitral valve back to the left ventricle. The circulation through the lungs is often called the *pulmonary circulation,* and the circulation through the other parts of the body is called the *systemic circulation.* Sometimes the circulation through the liver is referred to as the *portal circulation.*

Experiment to Show Normal Rate of Pulse and a Cause of Variation.—The student should take his own pulse while in a quiet state and record the number of beats per minute. Then he should engage in some exercise like running or wrestling. After this the pulse should again be taken and the number of beats per minute recorded as before. The cause of the variation from the first pulse rate will be apparent.

Experiment to Observe Circulation of Blood in Frog's Foot.—Cut a hole in a good sized shingle. Put a frog on the shingle, covering his body with a moist cloth to hold him in position. Place the web of the foot over the hole in the shingle and hold it in place by tying the toes to pins stuck around the margin of the hole. Then place the webbed part of the foot on the diaphragm of a compound microscope. Look through the lens and observe the movement of blood as it passes through the capillaries of the web membrane.

The Lymphatics.—The *lymphatics* are a series of pipe-like vessels, sometimes called capillaries, but smaller than the blood capillaries and designed to carry the lymph to the veins. They originate in the spaces between the capillaries and the cells, and gradually unite as they proceed toward the heart, finally forming a tube called the *thoracic duct,* about the size of a goose quill.

Through this tube the lymph is discharged into the blood. The thoracic duct also receives fatty food in fluid form brought by the lacteals from the small intestine, and transfers it to the blood. The blood passes the waste lymph to the excretory organs, since it is as necessary for waste lymph to be removed as for the waste collected by the veins from the cells to be removed. If waste lymph is not removed, its accumulation in the body will cause the disease known as dropsy.

Movement of the Lymph.—The movement of the lymph is slower and not so steady as the movement of the blood. The lymphatic system contains small sponge-like bodies called lymph glands placed somewhat irregularly in its course. These aid in eliminating material that is harmful to the body, and in destroying disease germs. Physicians sometimes force medicine by means of a syringe into the lymph that reaches the cells of the body. This quickly enters the circulation through the capillaries and becomes effective at once.

Hygiene of Circulation.—The cells of all parts of the body depend upon the circulatory system to deliver their food and oxygen and to remove their waste products. It is therefore clear that good circulation promotes good health, and it becomes our interest both to guard and to stimulate the circulation in every possible way.

Effects of Good Circulation.—A well-nourished body has the effect on the mind of producing abundant energy, alert thinking and light spirits; and on the body, of causing good muscular control, bright eyes and glowing color. Good circulation is one main reason for the charm of many people who possess attractive personalities. Good circulation cannot be kept up when other functions of the body are neglected. The law of co-operation of all parts of the body prevents that. All that promotes the general health promotes good circulation, and good circulation promotes the general health.

Effect of Exercise.—Action of the muscles increases the rate of circulation. A certain amount of daily physical exercise is necessary to prevent the blood from flowing sluggishly. Too slow a rate reduces the number of circuits about the body and, as the blood is reinforced with oxygen during each circuit, it reduces the supply of oxygen to the cells of the body, and retards the removal of wastes. Too little exercise makes people dull and listless. About four miles of walking in outdoor air daily is good, but some people are not strong enough for this, and should not overtax themselves in the effort. Housework in ventilated rooms is one substitute for walking. Fresh air during the taking of exercise is essential, for the blood must have oxygen.

Again, the rate of blood flow may be increased too much by too violent exercise. Many young athletes have injured their hearts for life by too great exertion in athletics.

Sluggish circulation tends to weaken the power of the body to resist colds. Habitual care of the health, including the taking of outdoor exercise, sufficient food and plenty of rest are the preventives and the only safeguards against colds. Prevention is worth more than cure.

Ductless Glands.—Ductless glands are glands that pass substances, known as *hormones,* not through ducts, but directly into the blood, which diffuses them throughout the body. In this respect they differ from such glands as the salivary glands, which discharge their principal products through ducts directly into the parts where they function. Among these glands are the *thyroid,* the *spleen* and the *adrenals.*

The thyroid glands are located one on each side of the esophagus just below the larynx. Although they apparently do not form a part of any system, they are important because of their influence on the life processes of the body. The secretion which they provide in some way affects the nutrition of the body. In the absence of the secretion, a child, as he grows, may develop a misshapen body with weak limbs and a dull brain.

The spleen is near the lower wall of the stomach and is always well supplied with blood. Its use is not fully known and it can be removed from the body without serious results.

The adrenal glands are two in number, each about the size of a walnut, and are situated one in front of each kidney. They influence the action of the muscles in the walls of the arteries by means of their secretion, and if destroyed cause a serious disease in the blood.

Coordination.—The function of these internal secretions, which are chemical, appears to be to coordinate the work of different parts of the body, that is, to influence the various parts of the body machine so that they will work in harmony and move at the right time and in the right order.

It has been discovered that certain glands which ordinarily discharge substances into various parts of the body through ducts

also produce internal secretions of great use to the body. The *pancreas* is one of these glands. It has been found that this organ not only discharges an important digestive fluid through ducts into the intestine, but it also produces another substance called *insulin,* which passes by diffusion directly into the blood. Insulin, it seems, is necessary to other organs to insure assimilation of sugar. Lack of production of this substance by the pancreas is the cause of the disease known as diabetes.

Effect of Alcohol on Circulation.—If taken in small amounts alcohol sometimes increases the rate of the heart-beat. The habitual use of alcohol is believed to cause the accumulation of fat around the heart and within the heart muscle, producing what is known as fatty degeneration of the heart. Large doses may cause paralysis of the nerves of the heart, which may account for heart failure.

The continuous use of alcohol may cause dilation of the capillaries, increasing their blood capacity. The effect is often apparent in the unusually red face of a person who drinks. This dilation of blood vessels, seen in the capillaries of the face, goes on throughout the arteries if the use of alcohol is continued. The arteries are likely to lose their power of contraction and remain dilated. Such a condition is said to favor secretion of lime in the walls of the arteries, making them brittle, so that unusual blood pressure may cause bursting of an artery, resulting in the formation of a clot. If the clot is on the brain, as often happens, the result is apoplexy, which is frequently fatal.

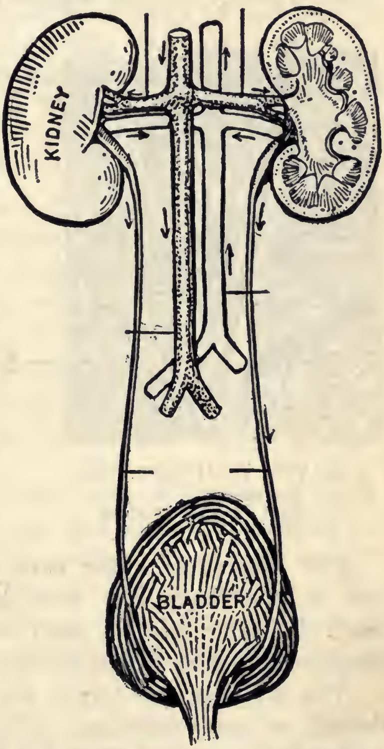
Alcohol also has its effect on the blood itself. It injures the white corpuscles and reduces their ability to fight disease germs.

Effect of Tobacco Upon the Heart.—Tobacco, when used extensively, acts as a poison on the nerves of the heart, causing it to beat irregularly and rendering close application to work arduous on account of palpitation. The habitual use of cigarettes by boys has a harmful effect on the quality of the blood, causing inadequate respiration of the cells, thus hindering the release of energy necessary for the best physical and mental development.

Assimilation.—Assimilation is the process of changing the digested food into living tissue. It takes place in the cells through-

out the body, after the blood has delivered the nutrient to the cells. Each cell of the body takes up a bit of this food and transforms it into a substance similar to itself. In this way the body of a growing child increases in size. Some of the digested food is immediately oxidized in the blood, producing heat energy.

Sugar in the form of glucose and protein in the form of peptone are carried directly to the liver after absorption from the intestines, reaching this organ through the portal vein. As the blood leaves the liver it contains a small amount of glucose which is quickly oxidized in the blood, producing heat energy. Peptone, on reaching the liver, undergoes certain changes. Some of it is oxidized, but the greater part is carried in the blood current to the cells of the body, where each cell assimilates as much as is needed for its growth and repair.



THE KIDNEYS AND THE BLADDER
They eliminate waste.

Excretion. — Excretion is the process of throwing off the waste substances of the body. These substances consist of *water, carbon dioxide, urea, mineral matter* and *undigested material.* All wastes except undigested material are primarily excreted in solution from the cells of the body by osmosis. They pass into the blood current and are carried to the different organs of excretion.

The organs of excretion are the *kidneys,* the *skin,* the *lungs,* the *liver* and the *large intestine.*

The chief work of excretion is carried on by the kidneys, which take away water containing urea and other waste matter in solution.

The kidneys are two bean-shaped organs, each about the size of an ordinary potato, situated in the lower part of the abdomen. They are made up of innumerable small tubes. These tubes unite into one larger opening on the side of each kidney, from which the water is passed into the bladder and eliminated from the body.

A SECTION OF HUMAN SKIN
1. Epidermis.
2. Duct of a sweat gland.
3. Hair follicle.

The lungs throw off carbon dioxide and water vapor by osmosis in the process of respiration.

The skin contains glands called *sweat glands* that excrete perspiration or sweat, consisting of water with waste matter in solution. The liver assists in excretion by throwing off poisonous wastes with the bile into the intestines. The bile aids in digestion by breaking up fats so enzymes may act on them. Undigested material is expelled from the large intestine.

The skin is an organ both of excretion and of protection and its inner layer may serve as an organ of absorption, since when the epidermis, or outer covering, is removed, it permits drugs or poisonous substances to pass into the blood vessels.

The skin has two layers, the *dermis,* or inner, and the *epidermis,* or outer covering. The dermis is a tough, elastic network of tissue which contains blood vessels and nerves. It is covered with a thin layer of cells designed to protect it. This outer layer which is called the epidermis, or the *cuticle,* contains neither nerves nor capillaries. The nails and the hair are developed from it. Corns and callouses also are growths of the epidermis.

Hygiene of Excretion.—Health cannot be maintained unless the wastes of the body are daily eliminated.

The interior of the body must be kept free from wastes; otherwise it is poisoned. Cleanliness pertains to every cubic inch of the body and not merely to its surface. Each cell must be drained of its wastes. Only by drinking plenty of pure water, by taking baths regularly to keep the pores of the skin open, and by due attention to the daily elimination of waste matter from the intestines can excretion of the wastes of the body be assured. Each organ—kidney, lungs, skin, liver, and large intestine—has its specific function in eliminating waste and each is essential to life.

SUMMARY

The circulatory system consists of the heart, arteries, veins and capillaries through which the blood constantly moves.

The blood carries food and oxygen to the cells of the body and carries wastes away from the cells.

The heart, a muscular organ, forces the circulation, and the arteries, veins and capillaries are the vessels in which the blood circulates. The heart has valves and acts like a double pump.

The blood is composed of red and of white corpuscles, and plasma which contains nutrients.

The red corpuscles are flat circular cells with rounded edges, each having a depression. They are cells without a nucleus, are microscopic in size and countless in number. They carry oxygen.

The white corpuscles are colorless cells of irregular shape, having a nucleus. They are microscopic in size and not nearly so numerous as the red corpuscles. They destroy disease germs.

The blood constantly changes in composition in passing through the body, as it takes up and gives off nutritive material and wastes.

Blood coming from a cut or other bodily injury usually forms a jelly-like substance called a clot. A clot aids in stopping the flow of blood from a wound. It is dangerous to have a clot form in the body.

The pulse is a throb caused by the movement of the blood in the arteries. The rate and strength of heart beat may be measured by the pulse.

The blood makes a complete circuit, passing through the four parts of the heart, the arteries, veins and capillaries.

The lymphatics are a series of pipe-like vessels similar to capillaries but smaller. They carry lymph. The lymphatics aid in getting waste material into the blood current and in conveying the fatty food from the intestines to the blood.

Good circulation promotes health. Exercise promotes good circulation.

The use of alcohol may cause fatty degeneration of the heart, paralysis of the heart nerves, dilation of the blood vessels and injury to the white blood corpuscles.

The use of tobacco makes the heart's action irregular. In the young, particularly, it checks physical and mental development.

Assimilation is the process of changing digested food into tissue after it enters the cells.

Excretion is the process of throwing off the waste substances of the body.

The organs of excretion are the kidneys, the lungs, the liver, the skin and the large intestine.

The importance of excretion to the health cannot be overestimated. Drinking plenty of water, bathing the body and daily elimination of all wastes are essential to the maintenance of health.

Fact and Thought Questions

1. Describe the structure of the heart.
2. State how the heart is adapted by structure to do its work.
3. How does the structure of an artery differ from the structure of a vein?
4. Trace the course of the blood in the systemic circulation.
5. Give the functions of the circulation of the blood.
6. What changes occur in the blood during its circulation?
7. Describe an experiment to show variation in the pulse.
8. State the effect of the habitual use of alcoholic drink on the heart.
9. Describe the effect of the habitual use of tobacco on the heart.
10. Describe the position, structure and chief function of the arteries.
11. From what blood vessels are digested nutrients given to the tissues?

12. In what way does it help us to know the direction in which blood flows?
13. Name three points where you can easily feel your pulse.
14. What are the ductless glands? How do they act?
15. How does the use of water aid our circulatory system?
16. Complete the following statements:
   (a) Oxygen is carried in the blood by the ———.
   (b) Blood vessels carrying blood from the heart are called ———.
   (c) The blood gives ——— to the air sacs of the lungs and takes ——— from them.

Projects

1. Obtain and examine carefully the heart of a sheep or cow. Compare it with the human heart as described in the text.

Outdoor Observation

Note change of pulse when standing, walking, climbing and running.

References

The Human Mechanism.............................*Hough and Sedgwick*
The Human Body...*Martin*

CHAPTER XXXIV

OUR NERVOUS SYSTEM AND HOW IT WORKS

In studying the muscular system, the circulatory system, and the other wonderful working parts of our bodies, we have seen how each has its own vital task to perform. We have seen, too, that each system depends on every other system to such an extent that if one breaks down or fails to work properly all others are seriously affected. Good "team work" is necessary for health.

So complicated and so interrelated are our bodily processes that general control and direction are necessary for bodily health and for usefulness. This is the particular task of our nervous system, consisting of brain, spinal cord and nerves.

We may think of the brain as in authority, recording and classifying information coming from all parts of the body, deciding on action and issuing orders to the muscles. For this work the nervous system becomes the bodily telephone exchange. The nerves are the individual wires, reaching every part of the body. The spinal cord is a trunk line, gathering these wires into large groups. The brain acts as a central switchboard.

This wonderful apparatus is automatic to a surprising extent, in part from habit, having made the same connections with certain muscles for certain acts, over and over again. How this delicate, sensitive apparatus is constructed and protected and how it works is a story well worth knowing.

The word coordination is used to express the idea of the coöperation, or working in harmony, of the various parts of the body. You have undoubtedly noticed that in as simple an act as spreading butter on bread, one hand holds the bread, and the other the knife, and the movements of both hands are such as to effect the purpose desired. Numerous illustrations of coöperation of parts of the body may easily be found. They occur in dancing,

running, using a sewing machine, playing a piano and in doing all kinds of manual work.

In the study of the life processes of your body you must have noticed the cooperation among its internal organs. It is necessary that the activities of the various organs be so directed that perfect teamwork is secured. To accomplish this there must be a directing center, connected with all parts of the body, to receive information and to issue orders. This center is the brain and its connections are made through the spinal cord and the nerves. Together they form the *nervous system.*

Cellular Structure of the Nervous System.—In the brain and the spinal cord two kinds of nerve tissue are found, one composed of *gray matter,* the other of *white matter.* The gray matter contains a vast number of cells, somewhat irregular in shape, from most of which minute branches called *dendrites* are given off. These are the parts that enable the nerve cells to communicate with each other. The white matter is made up largely of *nerve fibers.* Each fiber contains a central part called the *axis cylinder,* which is the essential part of the nerve, since it transmits the nerve messages to and from the brain. Around the cylinder is a sheath and outside of this a thin covering of connective tissue. The axis cylinder of each nerve fiber is found to connect, in one place or another, with at least one central cell of gray matter. Each cell and its branches, including the axis cylinder, form one unit of the nervous system called a *neuron,* or nerve.

Parts of the Nervous System.—The principle divisions of the nervous system are the *brain,* the *nerves* and the *spinal cord.*

The Brain.—The main parts of the brain are the *cerebrum,* the *cerebellum* and the *medulla.*

The Cerebrum.—The cerebrum is the seat of thought. It is composed of two hemispheres closely connected by nerve fibers. It forms over eighty per cent of the brain, lies over and above the other parts, and is composed of a mass of white nerve tissue covered with a thin layer of gray nerve tissue about one-eighth of an inch thick containing many large cells. The surface of the cerebrum is formed into folds, or *convolutions,* which greatly

increase its area, so that it would cover, if spread out, nearly four square feet. All this area contains nerve cells in the outside layer. Each of these cells has many fibers, one of which develops a covering, or sheath, and becomes a nerve thread which connects it with other cells of the brain.

THE CEREBRUM OF A MAN'S BRAIN
Showing the hemispheres and their convolutions.

The Cerebellum.—The cerebellum lies just below the cerebrum. It makes up about sixteen per cent of the brain and is similar in structure to the cerebrum. It acts as a balance wheel and regulates the movements of the body. It has nothing to do with the origin of thought or with the vital processes of life.

The Medulla.—The medulla is a wedge-shaped organ which forms a connecting link between the spinal cord and the brain. It has an outside covering of white nerve tissue which lies over a central mass of gray tissue, and it gives off several pairs of nerves. It presides over the action of the respiratory system, controls the contraction of arteries, and regulates the movements of the esophagus in swallowing.

The Nerves.—Certain cells in the brain and in the spinal cord function as master nerve cells. Connected with them are fine thread-like organs, called nerves or neurons, which pass to all parts of the body, and afford a method of communication with the brain. They make a system that may be compared with a complicated telegraph system. When a nerve in any part of the body is irritated, the nerve transmits the impulse to the brain, where it causes a sensation. The carrying of impulses is the chief duty of the nerves. Nerves that carry impulses to the brain are called *sensory nerves* and those that transmit orders from the brain to any part of the body are called *motor nerves.*

The Spinal Cord.—The spinal cord is an organ about eighteen inches long and about one-half an inch in diameter, composed of nerve tissue. It lies in the tubular cavity formed by the bony rings of the backbone which protect it from injury. It connects with the brain at the base of the skull, and extends downward almost to the level of the lowest ribs. Like the brain it is composed of gray and of white nerve tissue, but unlike the brain the white tissue is on the outside and the gray tissue underneath. The cord is smooth and not of uniform size in its whole length. It gives off thirty-one pairs of nerves through openings between the rings of the backbone. These nerves function when directed to act by the brain. For instance, when a person desires to run, his brain sends an order to the spinal nerve cells and they in turn transmit the order over the nerves to the muscles used in running. In this way all orders for voluntary motion are given by the brain.

Reflex Action.—Reflex action is a term used to denote the power of the spinal cord to give directions for action without the aid of the brain. The purpose of reflex action is twofold, to protect the parts of the body from injury, and to relieve the brain of work by controlling important processes of the body.

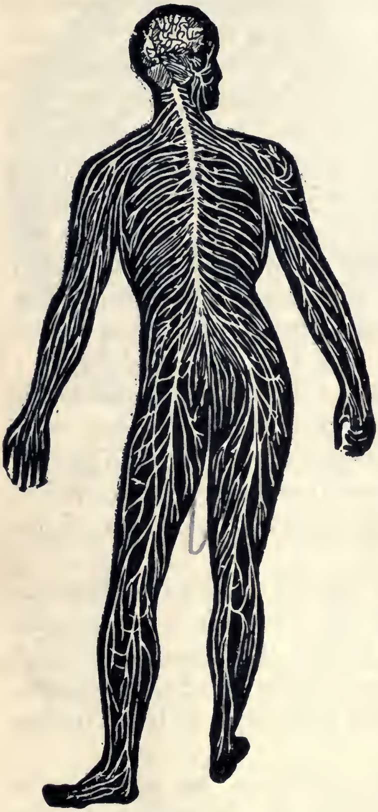
The way in which reflex action protects the body is illustrated when you quickly withdraw your hand from a hot iron with which it has come in contact. Before the sensation of heat reaches the brain, the spinal cord has already directed the muscles of your hand to withdraw it, thus protecting it from further possible injury.

The way in which reflex action relieves the work of the brain may be illustrated by reference to the digestive and other vital processes of the body. All of these are controlled by the spinal cord. They are said to be carried on unconsciously, which means that the brain does not give them attention.

All habitual movements of the body are governed by the spinal cord. They are reflex actions. When first used, the brain cells give the orders to the spinal cord to act, but gradually the spinal cord assumes control, thus relieving the brain and leaving it free

for other work. Skill in any art can be acquired only by the aid of reflex action.

The Sympathetic System.—The sympathetic system consists of two chains of *ganglia,* or collections of nerves, running along each side of the spinal column. There are twenty-four ganglia in each chain. These have branches connecting them with the vital organs of the body, the heart, lungs, stomach, liver, intestines and kidneys. The action of the sympathetic system is under the control of the spinal cord, from which impulses are sent to the ganglia whose functions are to regulate the dilation of the arteries, the peristalsis of the intestine, the secretions of the various glands and other unconscious activities of the body. Whenever one organ of the body is affected by some unfavorable condition, all the other organs seem to be more or less influenced. This explains why this collection of nerves is known as the sympathetic system.



THE NERVOUS SYSTEM
The telephone system of the body.

Hygiene of the Nervous System.—The conditions necessary for the keeping of the nervous system in a normal state, so that it can perform all its functions well, are the same as those essential to the healthy activity of the other parts of the body, namely good food, fresh air, exercise and rest. Like all living cells of the body, nerve cells must have food for growth and repair, and oxygen to unite with the food for the production of energy. Exercise is necessary to insure

the full performance of their normal functions, as unused cells fail to develop. Rest after exercise is necessary to restore vigor. Sleep is absolutely essential to the health of the nervous system since it is during this period of rest that the brain cells recuperate. Most adults require eight or nine hours of sleep each day. It is well understood that children require more sleep than adults. Those under six should have from eleven to twelve hours of sleep daily, and those between six and eleven years need at least ten hours. Insomnia, or sleeplessness, on account of its disastrous effect on the nervous system, should be relieved as soon as possible.

Nervousness.—Nervousness is a lack of self-control. A person whose nervous system responds too readily to slight stimuli is said to be "nervous." This condition may be due to inheritance, to the use of a drug, to overwork, to eye strain or to other causes. If due to inheritance it can be partially overcome by the exercise of will power. If due to other causes it can be remedied by the removal of the cause. Cases have been known where relief came with the use of glasses properly fitted to the eyes, and other cases where cure was brought about by simply ceasing to overwork. If caused by the use of a drug or other bad habit, relief becomes a matter of self-control by the individual in overcoming the habit.

Conservation of Nerve Force.—Nervous force is a form of energy generated by oxidation of the food in the nerve cells. It is necessary for the accomplishment of work of every kind; hence the need of saving it for doing the things most essential to well being. Unfortunately, with the majority of people there is a tendency to waste nerve force by various forms of activity that serve no useful purpose, such as worry over trivial affairs, undue excitement, excessive indulgence in pleasure and loss of temper. All these are harmful and tend towards a state of health known as nervous exhaustion.

Effect of Alcohol on the Nervous System.—We have already learned how alcohol affects different parts of the body. Its most dangerous effect is on the nervous system. In fact it is through action on this system that all other parts of the

body are affected, since the nervous system controls, coordinates and adjusts all the organs of the body by means of stimuli or nervous impulses which it originates and transmits.

It is the function of the cerebellum to regulate and coordinate the impressions which it receives from the trunk and limbs of the body. The power of walking steadily and balancing the whole body properly depends upon the normal functioning of the cerebellum. When this organ is disturbed by alcoholic poison there occurs more or less loss of control of the action of certain organs, especially of the lower limbs. Hence the staggering movements of the intoxicated man. Precision of movements of any kind is rendered impossible.

It is an accepted fact that alcohol and similar drugs attack the more complex and more delicate parts of the body and seriously injure them. Alcohol from the first has an unfavorable influence on the finer brain cells. Since the brain is the organ of the mind, the effect on thought and motion is soon apparent in the conduct and work of man under the influence of liquor.

Effect of Tobacco on the Nervous System.—Nicotine, the active agent in tobacco, acts on the nervous system as a poison. Although the use of tobacco is not so serious in its effects as the use of alcohol and certain other drugs, it often brings on a nervous derangement known as "tobacco heart" and sometimes causes a nervous disorder of the retina of the eye.

SUMMARY

Coordination means the working together in harmony of the various parts of the body. This is brought about by the nervous system.

The most important parts of the nervous system are the brain, the spinal cord and the nerves.

The brain is composed of three principal parts, the cerebrum, the cerebellum, and the medulla.

The cerebrum is the seat of thought.

The cerebellum regulates the movements of the parts of the body.

The medulla presides over and controls the action of the respiratory system, the contraction of arteries and the process of swallowing.

The spinal cord is an organ of nerve tissue lying within the rings of the backbone. It connects with the brain and also, by nerve branches, with all parts of the body.

Reflex action is a response to an impulse brought to the spinal cord by a sensory nerve, without direction from the brain.

The conditions necessary to keep the nervous system in a normal state are fresh air, proper food, exercise and rest.

Nervous force should be conserved. Some activities which waste nervous energy are worry, undue excitement, loss of temper and over-indulgence in pleasure.

Self-control is essential. It enables the mind to direct all activities of the body towards a useful end.

It is necessary to avoid certain things that are likely to harm the nervous system, such as excess of mental work, eye strain and use of drugs.

Use of alcohol, tobacco and other drugs is injurious to the health of the nervous system.

Fact and Thought Questions

1. Tell how parts of the body cooperate in spading a garden; in swimming.
2. Name the most important parts of the nervous system.
3. Describe the structure of the brain.
4. Describe the structure of the spinal cord.
5. What is a neuron?
6. Give the functions of the brain.
7. What is reflex action?
8. Discuss the importance of reflex action.
9. Describe the structure of the sympathetic system.
10. State the functions of the sympathetic system.
11. Does loss of temper make you feel physically better, or worse? Why?
12. Name some way in which you have wasted nervous energy in the last day or so.
13. Name several bodily habits that will tend to keep you "clear-headed."
14. Why is exercise beneficial after severe study or examinations? Should such exercise be light or heavy?

Projects

1. Determine by experiments what parts of the body are most sensitive to touch.
2. Try simple experiments to show reflex action.

Outdoor Observation

1. Observe how various parts of your body coordinate in walking, running, jumping or in some other physical act.
2. Observe coordination in the motions of animals and birds.
3. On the way to school, note acts you commonly perform consciously, and acts or motions you ordinarily perform without conscious thought.

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The Human Body..*Martin*

CHAPTER XXXV

BACTERIA, HELPFUL AND OTHERWISE

Gulliver in his imaginary travels in Lilliput never beheld such tiny plants as actually exist in countless numbers all about us. Many of them are so small that a single plant is not visible to us unless our sight is aided by the most powerful microscope.

These vegetable growths, or bacteria, are everywhere. They lodge and grow in the cavities of our bodies. They are found in the soil. Thousands may inhabit a drop of water. They even float in the air and are drawn into our lungs with every breath.

Like larger plant life, some of these miniature growths are very helpful to us in preparing certain foods and in increasing the fertility of the soil. Others are highly dangerous, making food unfit to eat or, if they get a foothold in our bodies, causing dangerous diseases.

Scientists have rendered us a wonderful service through their studies of these tiny plants. Now many facts are known about bacteria that enable us to use some of them for our good and to protect ourselves better against the dangers of the others. It is highly important that we have some knowledge of how bacteria affect our daily lives.

Bacteria are minute plants, the smallest living things of which we have knowledge. A single plant is less than one ten-thousandth of an inch in diameter. Examined with the highest power of the microscope, each plant is seen to consist of a bit of protoplasm surrounded by a cell wall and, in most species, without a definite nucleus. Many kinds can move from place to place by means of hair-like organs extending from or through the cell wall. The rate of movement is often very rapid.

Types of Bacteria.—There are three general types of bacteria, classified according to form: *spherical, rod-shaped* and *spiral.* The simplest form is the spherical, which sometimes multiplies in such a way as to produce long chains. Rod-shaped bacteria are so

named because of their resemblance to minute rods. As they grow they break in two, or lengthen into long slender threads which finally break up into rods. Some have tiny organs of motion and are very active. The third type is spiral. It should always be kept in mind that all forms of bacteria are so tiny that they can be observed only by the aid of high powers of the microscope.

BACTERIA—THE SMALLEST KNOWN PLANTS
A—Spherical.
B—Rod-shaped.
C—Spiral.

Bacteria may be placed in two classes: first, those that live on decaying matter; second, those that get their food from higher living organisms. The first class are known as *saprophytes,* the second class are known as *parasites*. The latter include the disease-producing bacteria.

Life History.—As in the case of all other living things, food, moisture, oxygen and some degree of heat are necessary for the growth and development of bacteria. They respond most favorably to a temperature about that of our own bodies, and to a location not exposed to direct sunlight or fresh air. If exposed to bright sunlight they perish rapidly. When conditions are right, each bacterium grows to full size, and immediately divides into two equal parts, thus producing two individuals.

When conditions for life are unfavorable, some bacteria are able to continue their existence by developing a thicker cell covering which protects them. While in this form they are called *spores*. Although they seem lifeless, with the reappearance of favorable conditions, especially of heat and moisture, they

resume their activities and give evidence of life. The resistance of these spores to adverse conditions is so great that they are able to withstand high temperature and the action of strong chemicals.

Bacteria are present practically everywhere, in the air, in the water, and in the earth. They exist in the fluids and tissues of plants, animals, and man. Some forms are harmless and apparently of no special value to man; other forms are of the greatest service to him; and still others are very harmful, causing dangerous communicable diseases among animals and man and much injury to vegetable life.

Other forms of plant life which resemble bacteria in many respects are molds. The molds are usually visible to the naked eye and grow in the form of threads. They form on moist foods and aid in the process of decay. Some molds are useful in developing flavor in certain kinds of cheese.

Experiments.—A single bacterium cannot be seen with the naked eye. They can, however, be seen in masses or groups, called *colonies.* For scientific study, *cultures* or growths of bacteria are made on *mediums,* substances on which bacteria thrive, such as gelatin or agar-agar. The medium used and the test tubes or the flat saucers, called Petri dishes, which contain it, must be sterilized, or made free from germs, usually by heat. The containers must be kept plugged or covered until needed.

To prepare an agar-agar medium, add to 1000 grams of hot distilled water 10 grams of agar-agar, 5 to 10 grams of beef extract, 10 grams of peptone, and 5 grams of salt. Boil the mixture. Filter the mixture through absorbent cotton into sterilized test tubes and seal the tubes. Each tube should be about one-quarter full. When required for use, melt the contents of a tube in a double boiler and pour while hot into sterilized Petri dishes or test tubes. A gelatin medium may be formed by substituting 100 grams of jello or French gelatin for the agar-agar.

To Show the Growth of Bacteria and Molds in Air.—Use four test tubes containing gelatin or agar-agar. Set aside

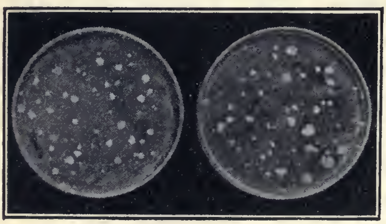
one tube without removing the plug, to serve as a check, or control. Label it 1.

Expose the contents of the second tube for several minutes to the air of an empty classroom. Plug the tube, and label it 2. Similarly, expose the contents of the third tube to the air of the classroom at the close of a recitation, and expose the contents of the fourth tube to the air of the school yard. Label these tubes 3 and 4.

Keep all these tubes in a warm, dark place for two or three days. At the end of this period count the colonies of bacteria and record the number observed in each tube. Also notice whether molds have formed. Compare the numbers of colonies in the different tubes. State your conclusions.

To Determine the Presence of Molds in Bread.—Place a piece of fresh bread in a can or box, and leave it for three or four days in a warm, dark, moist place, where there is little circulation of air. At the end of this time examine the bread. What do you observe? How should bread be kept to prevent molds forming on it?

To Determine the Presence of Bacteria in Milk.—Using three prepared Petri dishes, set one aside without uncovering, for a control. Label it 1. Uncovering the others, spread on the medium of one a drop of fresh milk, and on the second a drop of milk a day old. Label them 2 and 3. Leave the dishes in a warm, dark place for two or three days, and then examine the contents of each. Record the results, stating the number of colonies observed in each case. What is your conclusion?



BACTERIA IN PETRI DISHES
Each white spot is a colony of many thousands.

To Determine the Presence of Bacteria and Molds in Water.—Using three prepared Petri dishes, set one aside without uncovering, for a check or control. Label it 1. Uncovering the others, spread on the medium of one a drop of ordinary drinking water, and on the second a drop of rain water. Label

them 2 and 3. Leave the dishes in a warm, dark place for two or three days and then examine. Record the number of colonies in each dish. Notice whether molds have formed. State your conclusions.

To Determine the Presence of Bacteria on the Teeth.—Using three prepared Petri dishes, set one aside, without uncovering, for a check or control. Label it 1. Uncovering the others, spread on the medium of one of them scrapings from the teeth before brushing, and on the other scrapings from the teeth after brushing. Label these dishes 2 and 3. Leave them in a warm, dark place for two or three days and examine as before. Record the results, stating the number of colonies observed in each case. State your conclusions.

Experiment to Show the Conditions Favorable to the Growth of Bacteria.—Prepare four cultures in Petri dishes. Expose one culture in a warm, dark place having a moist atmosphere; a second in a very cold, dark place having a moist atmosphere; a third in a warm, light place having a moist atmosphere; and a fourth in a cold, light place having a moist atmosphere. Leave the cultures for several days and then examine. Count the colonies of bacteria you see in each culture and decide what conditions are most favorable for growth.

Soil Bacteria.—Certain kinds of bacteria, known as soil bacteria, have the power to decompose, or break up into simpler forms, organic compounds containing nitrogen, and to recombine them into nitrates that may be taken up in solution by the root hairs of plants and used as raw material in making plant food.

These bacteria act on and decompose such organic matter as dead animals and plants, manure and sewage. Were it not for the work of soil bacteria the earth would not be habitable. They act as middlemen between the lifeless and the living world and thus make possible the use of the same elements over and over again in the production of new organic matter.

Nitrogen-Fixing Bacteria.—Although the air we breathe is about 80 per cent nitrogen, the only living creatures that are able to take this nitrogen directly from the air are certain

bacteria, called nitrogen-fixing bacteria, which grow on some plants. These bacteria change the nitrogen into soluble nitrates, valuable plant food, which root hairs, or tiny rootlets of the plants, absorb.

Roots of a Pod-Bearing Plant Showing Nodules

For centuries past, farmers have noticed that crops raised on soil which has borne clover or other members of the legume, or pod-bearing, family during the preceding year are always especially prolific. The reason for this has now been learned. Investigators discovered on the roots of the plants of this family slight enlargements called tubercles, or nodules, which contain vast numbers of nitrogen-fixing bacteria. These nitrogen-fixing bacteria are of invaluable service to farmers in feeding plants on which they live and in enriching the soil for other crops.

Other Forms of Bacteria.—There are also forms of bacteria that are useful to the dairyman, as they develop desirable flavors in butter and cheese. These foods are said to ripen when they have been subject to the action of such bacteria.

Other bacteria are helpful in manufacturing processes. Certain varieties soften the useless woody parts of hemp and jute, so that the fibers used in making rope are released. Others release the flax fibers needed in the making of linen. Other bacteria eat out the harder parts of animal hides, so that they may be made into soft and pliable leather. Still other bacteria improve sponges by ridding them of a slimy waste.

Yeast.—Other forms of plant life, somewhat similar to bacteria, are the yeasts. They are useful in making bread. After

the ingredients have been mixed to form a solid sticky mass, called dough, the yeast is added, and the material set aside in a warm place to rise. The yeast plant grows rapidly, giving off carbon dioxide. This gas fills the dough full of small bubbles, causing it to swell. The dough is then baked and becomes bread. If baked without yeast, bread is very hard and compact.

Bacteria and Food.—Bacteria of decay render invaluable service to mankind by the decomposition of useless organic material so that it may become available to plants for the production of new food. They are, however, a constant and common source of annoyance, as they quickly render food, especially protein food, unfit for eating, if they have access to it. Nearly all kinds of food, especially milk and meat, spoil in a short time if not protected from their activity. When they attack protein food, it often happens that poisonous substances, known as ptomaines, are formed, which cause serious illness to those who eat the food. To-day all classes of people are interested in protecting food from the decaying action of bacteria. There are several methods of preventing their attacks.

Preservation of Food.—Preservation of food is closely related to the study of bacteria. Largely on this account the study of bacteriology is considered an essential part of the preparation of all who expect to deal with the problems of domestic science.

Food may be kept from spoiling for a long time by any one of five methods: *canning, drying, smoking, pickling,* or *cold storage*. In all these methods the important thing is to prevent the activity of bacteria, as by doing this the chief cause of the decomposition or spoiling of food is stopped. It is well known that a high degree of heat will kill bacteria. It is also a well-established fact that bacteria require a considerable degree of moisture to insure their reproduction, growth and development, and it has been learned from experiments that they will not develop at all in foods that are fairly dry. The preservation of food, then, depends either on the killing of bacteria or on making their environment such that they will cease to act.

Canning.—In ordinary canning of meat or fruit three steps are necessary. First, the substance, after being washed, is

subjected to a high degree of heat in order to kill all microscopic forms of life; second, the vessels or cans in which the material is to be placed are thoroughly sterilized; and third, the material, while highly heated, is put into the vessels or cans and sealed hermetically, that is, so that no air can get into the can.

In sealing fruit jars, a rubber ring is inserted between the jar and the cover, which is clamped or screwed down. As the

SHUTTING OUT HARMFUL BACTERIA

The vegetables are preserved by heating in the boiler to destroy germs and by sealing in sterilized glass jars.

jar cools the air inside contracts, forming a partial vacuum. Outside air pressure aids in forcing the rubber tightly into every crevice.

If even a single bacterium chances to survive the heating process and gets into the can, the work of canning will be use-

less, as this single bacterium will multiply and there will soon be a vast number in the can that will cause the food to spoil.

Sometimes the material to be canned contains bacteria in the form of spores. These are not easily killed by boiling. They are not commonly present in fruit, but in material like green corn, green peas and green beans they are often found. Only a very high degree of heat will destroy them.

Drying.—Drying is one of the most common methods of preserving food. It is nature's method. You have probably observed that seeds will keep for a long time if protected from moisture. You know also that flour, meal and foods made from these seeds will keep in good condition if absolutely dry. Bacteria and other microörganisms will not develop on them if kept dry.

Material of animal origin also may be preserved by drying. Most kinds of meat may be kept in this way. The Indians understood this and cut the flesh of wild animals into thin strips which they dried by the heat of the sun or otherwise. Meat thus dried will keep for a long time, as bacteria do not develop on it. Apples, peaches, plums, berries and other fruits may be dried and preserved indefinitely, if properly protected from moisture.

Smoking and Pickling.—One of the common methods of preserving fish and the flesh of animals is by smoking, after the substance has been well pickled, that is, soaked in a solution of salt water. This process is called *curing*. Hams, bacon and dried beef are preserved in this way. The smoke from burning wood is commonly used. Smoked meat will not be injured by bacteria for three reasons; it is too dry to support their growth, the smoke itself is not favorable to the development of bacteria, and salt is injurious to them. Certain food material may be preserved by pickling, without smoking.

Cold Storage.—The fact that low temperature will preserve all kinds of food is well known. Cold storage means the keeping of food in a building that is cooled artificially and kept at a low temperature even in the hottest weather. The idea of cold storage is modern. Buildings adapted for this purpose, cold storage plants as they are called, are now found in all large cities and in some small places. In the preservation of apples and similar fruits,

the temperature must not be allowed to get below freezing, as fruits are decomposed by freezing. Meats, however, including fish and fowl, will be suitable for use for an indefinite time if kept in a frozen condition, since freezing will prevent the development of bacteria. Cold storage plants for preserving food material are employed on a large scale by persons who expect to place it on the market at a time when the food has become scarce. The object, of course, is to sell the food for a higher price than it brings when it is abundant.

Other Devices for Preserving Food.—Most well-appointed homes have an ice chest or refrigerator. The ice chest will check but not wholly stop the growth of bacteria, so food is not so thoroughly protected as when in cold storage. Cool cellars are usually found in most homes. In rural sections, deep wells are often used as places in which to preserve food temporarily. Small buildings containing cold running water are often employed and are very useful and essential to the success of dairymen.

Formerly, dealers in food used various chemical substances to prevent food from spoiling. Often these were of a nature that would be harmful to the health of those who ate food thus preserved. Since the passage of the Pure Food and Drugs Act by the United States government the use of these substances has been greatly lessened.

When water evaporates it has a cooling effect. This method may be used for keeping foods cool. Tents are sometimes used in warm countries for storing perishable foods. They are placed in such a position that the air can move about them readily. Water is allowed to drip on the roof of the tent and run down the sides. As it evaporates, the tent is cooled. If the relative humidity is low, the cooling effect is very noticeable.

Parasitic Bacteria.—Parasitic bacteria are the most harmful kind since they live on other organisms and often cause disease. When they attack human beings they are popularly spoken of as germs or microbes. Diseases caused by bacteria or other germs are called *communicable* diseases. Among the most dreaded of these diseases are tuberculosis, typhoid fever and diphtheria. Their bacteria flourish especially well where filthy conditions prevail, but

they will not survive in surroundings that are perfectly clean and dry. It was this fact which Pasteur probably had in mind when he said: "It is within the power of man to cause the parasitic diseases to disappear from the surface of the globe."

How to Kill Parasitic Bacteria.—Bacteria may be killed by the application of intense heat, by exposure to strong sunlight and by the use of germicides. Heat may be applied to objects suspected of harboring bacteria by boiling, by steaming or by burning. Strong sunlight is especially efficient in killing disease bacteria and will destroy all bacteria directly exposed to its rays. *Germicides,* also called disinfectants, are chemical substances that kill by contact. Among the most effective of these are bichloride of mercury, formaldehyde and strong solutions of carbolic acid or of iodine. All are poisonous and so should be used only on the advice of a physician, or a health official.

Some germicides are used in solutions. Others, such as formaldehyde and sulphur dioxide, may be used as gas to disinfect a room or a building. Disinfection by poisonous fumes or gases is called *fumigation.*

SUMMARY

Bacteria are minute plants of which there are three types, spherical, rod-shaped and spiral.

According to their method of obtaining food, bacteria are divided into two classes, saprophytes and parasites.

Bacteria, under favorable conditions, reproduce rapidly.

Colonies of bacteria may readily be grown on gelatin or some other medium under proper conditions.

Yeasts and molds are forms of minute plant life closely related to bacteria.

Among bacteria useful to man are bacteria which give flavor to butter and cheese, bacteria which release the valuable fibers of flax and hemp, soil bacteria which change organic wastes to plant food, and nitrogen-fixing bacteria which take nitrogen from the air for use by plants.

Among harmful bacteria are those which cause food to spoil and those which cause disease.

Food may be preserved by destroying the bacteria it contains. Canning, drying, smoking, pickling and cold storage are methods of preserving food.

Disease bacteria are destroyed by exposure to strong sunlight, by boiling or burning objects containing them, or by the use of germicides—liquid solutions or gases which kill by contact.

Fact and Thought Questions

1. What are bacteria?
2. Give the characteristics of bacteria.
3. Describe an experiment to show the growth of bacteria on a sterilized substance.
4. Mention ways in which bacteria are useful.
5. Mention ways in which bacteria are harmful.
6. How may bacteria be destroyed?
7. Describe the canning of fruit, giving the reason for each step in the process.
8. Name several dried foods you have eaten.
9. Why does cold storage preserve foods?
10. Is it healthy to have very heavy shade close around a dwelling? Why?
11. What services do nitrogen-fixing plants render the farmer?
12. Name three ways of preserving and protecting food used in your own home.
13. How might you protect and preserve food supplies in a woods camp?

Projects

1. After sweeping a room place a little of the dust on sterilized agar-agar in a sterilized Petri dish, set aside, observe daily, note and record changes.
2. Using the compound microscope examine prepared mounted specimens of bacteria. Describe what you see.
3. Study the public food regulations of your community and prepare a brief abstract of them.

Outdoor Observation

On your way to and from school observe and note natural breeding places of bacteria, and unsanitary conditions from the bacteria standpoint, that might easily be remedied.

References

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CHAPTER XXXVI

PROTECTION AGAINST DISEASE

The true athlete considers it a matter of loyalty to himself and to his school to keep himself physically fit. Only thus can he give the best of himself for those he represents upon the ball field or track. It should be just as much a matter of loyalty to ourselves, to our country and to our future work, that we build up strength of body and of nerves to keep our blood clean and our heads clear.

We are thrilled, and rightly, at the accomplishments of some man or woman who does great things in spite of serious physical handicaps. They should ever be an inspiration to us, for they emphasize what great achievements an added capital of sound health should make possible.

We may have to work long and hard to accumulate money. Health we may begin to accumulate at once. The younger we are when we start, the better. It is in our power to store in our bodies energy and strength, and capacity to resist disease in the future. Good habits in protecting and building health, steadily continued, will bring their own reward in more and better work, in greater success, and in greater joy in life.

It needs no argument to prove the importance of good health. Upon its possession depend not only power to work well but also ability to enjoy life. All other factors that lead to happiness are of slight account in comparison with health. Good health improves physical appearance, increases power of attraction and tends to prolong life and to insure racial vigor. Sickness, on the other hand, has opposite effects and not only results in unhappiness but is also a source of great expense.

Causes of Disease.—Among the causes of disease are errors in diet; fatigue caused by overwork, worry and fear; contact with poisonous substances; and especially the presence in the body of microörganisms and other larger parasites.

Errors in Diet.—In the diets of most people there are errors that tend to produce ill health. It is a well known fact that

Americans eat too much protein food. The results of the best investigations show that of the total daily nutriment ten per cent protein is sufficient to supply the needs of the body. This means ten Calories of protein out of every one hundred Calories of food. Many people eat two or three times as much. Any amount above what is needed tends to putrify in the body and causes the production of uric acid, which is dangerous to health.

Another error is the wide use of the so-called refined foods from which the mineral salts, so essential to the health of the body, have been removed. White flour is not the only food substance deprived of these salts. Many foods have in the course of refinement lost valuable qualities. Included in this loss are the invaluable vitamins, the lack of which is believed to cause disorders like scurvy.

The eating of food kept from decomposition by the use of so-called preservatives like boric acid, formaldehyde and saccharin is believed to be bad for the health. Errors in diet should be avoided, as far as possible, in the great fight for the prevention of disease and the prolongation of life.

Fatigue.—Fatigue may be due to the lack of sufficient energy-making food to support prolonged work, or to the accumulation of waste material in the blood and in the cells, which acts as poison to the system. In the former case, relief will come from rest, sleep and a new supply of nutriment; in the latter case, by an increased amount of physical exercise and careful attention to the excretory processes of the body.

Poisons.—Not only is illness caused by poison produced in the body but often by external poison. The latter is especially apt to occur to persons engaged in work where lead, phosphorus and other chemicals are used, as in the making of glazed cards, Japan ware, matches, lead type and cosmetics. Workers engaged in industries where these poisonous substances are used should take every precaution to prevent their absorption into the system.

Parasites.—Although wrong eating, fatigue and poisons are the causes of much illness, a far greater number of dangerous diseases is brought about by the presence in the body of parasitic organisms, especially microörganisms.

Theories of Disease.—In early times, diseases were supposed to be carried by witches and other unfriendly spirits. In later times, they were believed to come from infectious particles that arose from decaying matter, stagnant marshes and filth of every kind, and were carried in the air. The germ theory of disease favored this belief. In recent years the theory that diseases are spread by means of such things as bedding, books, discarded clothing, and other objects has been popular.

The proof of the fact that many of the most dangerous diseases are caused by organisms of a parasitic nature, bacteria and protozoa, now tends to establish the belief that such diseases come from actual contact with these invisible germs. The theory that persons and not things spread disease is gradually becoming an accepted belief. The idea that disease germs retain their vitality in bedding, books or money for long periods of time is no longer credited, although the fact is not denied that towels, dishes and other objects recently used by those ill with a communicable disease may be the means of transmitting germs to others. It is no longer doubted that hand contact accounts largely for the spread of many common diseases, and that insect contact accounts for the spread of most of the rest.

Brown Bros.

A Bacteriologist at Work

Our chief attention should be given to the prevention of contact infection. You have undoubtedly often heard of diseases that are "catching" and know that persons affected with one of these diseases should be avoided, lest you yourself catch it. It is not the disease, but the germ that causes the disease that is caught. Each disease is caused by its own special germ. In some diseases

known to be catching, the germs have not yet been discovered. Nevertheless, it is believed that they are of germ origin as they have characteristics similar to those diseases that have been clearly proved to be germ diseases.

Microörganisms.—Germs of disease are always microorganisms, that is, organisms so minute that they can be seen only by the aid of the compound microscope. Many of them are bacteria. Diseases such as tuberculosis, typhoid fever, diphtheria and pneumonia are caused by bacteria and are among the most dreaded that afflict mankind.

Bacteria, however, are not the only forms of microscopic life that cause disease. Single-celled animals called protozoa may also cause them. Malaria, yellow fever, rabies or hydrophobia, sleeping sickness and some kinds of dysentery are caused by protozoa.

Protozoa are the cause of disease in animals as well as in man. They sometimes gain a foothold in the tissues of insects, birds, fishes, cattle and other animals, with disastrous results. Horses and cattle in Africa are killed in great numbers by a parasite transferred to their bodies by the tsetse fly. In America many cattle die from Texas cattle fever, or "tick," a disease that is believed to be caused by a protozoan.

Manners of Infection.—In order to control the spread of germ diseases it is necessary to know the routes by which the living germs of each disease leave the body of their victim, the means by which they are transmitted to other persons, and the avenues by which they gain entrance.

According to the disease, the germs are discharged from the bodies of the sick through the mouth and nose, through the organs of excretion, or through breaks in the skin.

They are carried to other persons on the hands of those who care for the sick, by flies and other insects, and by pets or by other agencies that have been in contact with the discharges from the bodies of the diseased.

The paths by which most of these germs enter the body are through the mouth in the food we eat, through the nose in the dust of the air we breathe, and through a wound or break in the skin.

Although the unbroken skin is usually a protection against disease germs, it sometimes happens that the germs causing boils and other skin diseases penetrate it at the roots of the hairs and at the openings into the oil and sweat glands.

Defenses.—The surest way to combat disease is to prevent the entrance of the germs into the body. Another most important way is to keep the body in the best possible condition for fighting germs if they do gain entrance. This is possible only by careful observance of the principles of hygiene.

The best way to keep germs from entering the body through the mouth is to use only sterilized food and water. Because heat destroys living germs, food that has been well cooked and water that has been boiled are always safe. Although infection through the air is not so common as was formerly believed, it is a known fact that some germs of diseases, notably those of tuberculosis, are spread by the dust that floats in the air.

Nature fortunately provides defenses against disease germs. There is the skin; there is the sense of smell which gives warning against the eating of decaying germ-laden food, and notifies us of the presence of foul gases. The nasal passages are guarded by hairs that prevent the entrance of much germ-laden dust. The trachea, through which the air passes to the lungs, is provided with cilia that constantly wave upward to keep back any germs. Avoidance of breathing through the mouth evidently decreases the chances of germ entrance by means of air.

The strongest natural defense against germs, however, in case they actually gain entrance to the tissues of the body, is the army of white blood corpuscles which is ever ready in the healthy body to attack and destroy these insidious foes. Furthermore, in the body that has been kept in the best possible condition by proper habits of life, there are substances known as *antitoxins* which tend to produce immunity, and certain other substances which are supposed to make the disease germs more susceptible to the attacks of the white blood corpuscles.

Immunity.—Immunity means freedom from taking disease. A person is said to be immune to a disease when, though exposed,

he does not catch it. Immunity may be either *natural* or *acquired.* It is said to be natural when it is inherited. It sometimes happens that a person does not become ill during an epidemic though all other members of his family are stricken. Such a person has natural immunity.

Immunity is acquired when it results from some treatment that counteracts the effect of the poison produced by the germs in the body. With certain diseases immunity from a second attack is gained by having the disease itself. Some condition is developed in the system, as a result of having the disease, that makes it impossible for the germs that produce it ever to thrive again in the body. Smallpox is such a disease. It is not known whether smallpox is caused by bacteria or by protozoa. The first method ever used to produce immunity from illness was employed to lessen the effects of smallpox. It is commonly called vaccination.

Vaccination.—Vaccination was discovered in 1796 by Dr. Edward Jenner, an English physician. It consists in introducing germs of cowpox into the system through a slight cut in the skin. The cowpox germs are obtained from the sores on the skin of a healthy calf, caused by vaccinating it with smallpox germs. These cowpox germs, called *virus,* produce a mild form of the disease and render the patient immune from an attack of smallpox for several years. Previous to this discovery, thousands of persons suffered from the dire ravages of smallpox which caused more loss of human life than tuberculosis now causes.

In the case of a smallpox epidemic general vaccination is the only means of stamping out the disease. Its use should always be advocated, and the prejudice against it in some sections should be overcome. Serious results that sometimes occur from vaccination are usually traceable to infections from germs other than those of the pure vaccine. Such infection should be avoided by having the vaccination performed only by a reliable physician who uses virus that has the guarantee of government inspection in its preparation, and who will give expert advice in regard to the care of the wound made in the skin.

Inoculation.—Inoculation is successfully used to prevent such diseases as typhoid fever. In the treatment to prevent typhoid fever a virus composed of lifeless typhoid germs is injected under the skin. Three treatments, about ten days apart, are sufficient to secure immunity. There usually results a slight swelling at the place of injection together with a little fever and depression, not sufficient, however, to interfere with one's daily routine of work. Typhoid inoculation was effectively used in our Army and Navy during the World War. No person is now allowed to serve in our Army or Navy who has not received this treatment.

Serum.—*Serum* is a clear fluid that appears when the blood of an animal clots. This fluid, except for the absence of certain protein matter which is in the clot, differs but slightly in composition from the blood plasma. When serum, obtained from the blood of an animal made immune by artificial means against some special disease, is injected into the bodies of human beings, it acts as a preventive of that disease by producing a substance that will overcome the toxins or poisons formed by the disease germs. This substance is called an *antitoxin.*

The use of a serum has been remarkably successful in the treatment and prevention of diphtheria. The diphtheria death rate has decreased more than seventy-five per cent. Other dangerous diseases now treated with serum are meningitis, an inflammation of the membranes of the brain and spinal cord, and lockjaw, a form of tetanus.

Action of an Antitoxin.—An antitoxin does not destroy the disease germs, as is sometimes supposed. What it does do is to overcome the toxins or poisons made by the germs, thus preventing their deadly effect on the nervous system.

Quarantine.—Quarantine is one of the most important methods in combating infectious diseases. It consists in keeping diseased and exposed persons separated from the well. Complete isolation not only of individuals but sometimes of infected communities becomes necessary in order to prevent the spread of disease. Quarantine is often used to stop travel on land or sea to prevent the spread of a dangerous infectious disease. Evasion of a quarantine ordinance is a punishable offense.

Diseases and Their Treatment.—

Tuberculosis.—Since tuberculosis is a preventable disease, it behooves every person to avoid as far as possible the conditions that favor its development. The essential condition for acquiring the disease is, of course, taking the germ into the body. It may enter the body through the mouth, the nose, or a wound. It may be in the food that is eaten, in the air that is breathed, or in the air that enters a wound. Once it secures a foothold in the lungs or other tissues of the body, it multiplies very rapidly under favorable conditions, and the *bacilli,* as the germs are called, may be carried by the blood current throughout the body. These produce a toxin or poison which is exceedingly harmful. This will not happen, however, if the body is in robust condition. Only when it is in a state of lowered vitality, "run down," as we say, are the germs able to thrive.

Tuberculosis may be contracted from tubercular excretions which are thrown into the air in coughing and into the street in spitting. Or it may be taken by kissing tubercular people or by using their eating utensils without sterilizing them. In general, foul air, dark rooms, damp surroundings, overcrowding, as in tenements, lack of sunshine combined with low altitude and other unsanitary conditions, are potent factors in the spreading of this disease.

Those ill with tuberculosis may themselves do much to prevent the spread of the disease by care in disposing of their sputum. It should be passed from the mouth into receptacles that may immediately be thrown into the fire. As the germs of the disease may be in the systems of people apparently well, it is unsanitary to sneeze or cough in a public place without covering the mouth or nose with a handkerchief, or to spit on the street. In some cities signs give warning that a fine will be imposed on any individual guilty of spitting on the sidewalk.

Cure of Tuberculosis.—Although tuberculosis exists in nearly all parts of the world and is easily taken by persons in a weakened condition, it is not impossible to cure it if steps are taken in time. In the treatment of the disease an abundant supply of fresh air and nutritious food are indispensable to the patient. Plenty of

rest and sleep, and freedom from all care and worry, are also necessary.

If possible the patient should go to a place of high altitude where the air is pure, cold and dry. In cities, sleeping porches and roof tents are often used with excellent results, because of purer air than in the house.

Publishers' Photo Service.

THE HOUSE FLY, A SPREADER OF DISEASE GERMS

Notice the long hairs on the fly's legs and body. These hairs become covered with filth and disease germs, which the fly carries and spreads about.

Typhoid Fever. — Since the germs of typhoid fever are largely spread in the excretions of its victims, it is often spoken of as a "filth" disease. It is spread by excretions which are thrown on the soil, from which the germs may find their way onto green vegetables, or into wells of drinking water, or other bodies of water from which people derive their daily water supply.

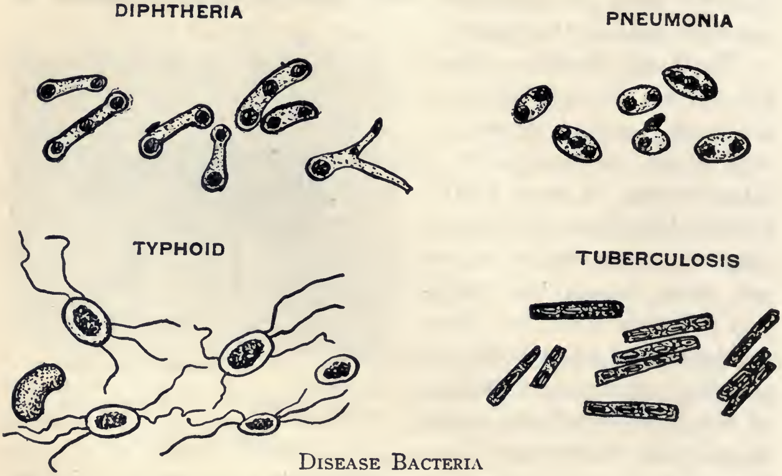
Typhoid is also spread by means of milk that has been polluted through the carelessness of unclean milkers, or of venders who have washed their cans in water that was polluted. Oysters grown in water that has received typhoid excretions are another cause of infection, if eaten raw.

It is a well established fact that the common house fly, after feeding on excretions, carries the germs on its feet and deposits them on the food we eat. This fact is so fully accepted that the insect is now called the typhoid fly.

It occasionally happens that the source of the disease is a person who has apparently recovered from an attack, but in whose system, sometimes in the saliva, the germs still develop. Such an individual is called a typhoid carrier.

Diphtheria.—Diphtheria is carried from person to person by sputum and by objects that are brought into touch with the infected parts. Hence it may be spread by dust that happens to

hold a bit of the dried sputum, by milk or other food that has become infected, and by animals. It may also be spread among children by exchange of pencils, gum, books, handkerchiefs or playthings. Until within a few years the lives of many children



DISEASE BACTERIA

were lost through diphtheria. Fortunately a remedy has been discovered which robs the disease of some of its terrors.

Prevention of Diphtheria.—Better even than the cure of a disease is its prevention. The taking of diphtheria is now actually prevented by the use of a mixture called *toxin-antitoxin* which, when introduced into the system, acts as a defense against the disease by counteracting the effect of the toxins that cause it. It has long been known that the cells of the body are able to produce a certain amount of a substance that aids in overcoming the toxins formed by the diphtheria germs. There is a battle of the cells in which, if the body cells win, the patient will recover. But on the other hand if the invading cells win, the patient will die. Toxin-antitoxin when injected into the body, seems to help the body cells in overcoming the poisons of the enemy.

The Schick Test.—The Schick test is extensively used to determine whether or not there is sufficient antitoxin in the blood of

a person to render him immune from an attack of diphtheria. It is a simple test made by the injection of one drop of a certain serum mixture into the skin of the arm.

If the skin shows no effects from the injection, the person tested is immune from the disease; but if a red spot appears, it

Syracuse Health Demonstration.

A Wise Precaution
Preventing diphtheria by the use of toxin-antitoxin.

indicates that there is not sufficient antitoxin in the blood, and therefore the person is susceptible to the disease. In the latter case injections of toxin-antitoxin are necessary to render the person immune. The treatment with toxin-antitoxin prevents the disease while the treatment with antitoxin cures it.

Sanitation.—Sanitation deals with the ways of making our surroundings healthful. It includes the cleanliness of the home and the home premises, and may involve larger problems, such as the elimination of mosquitoes or other insects from a tract of land or the removal of unwholesome conditions.

In selecting a site for a home, one should make sure that the land is well drained, that an ample supply of pure water is easily available, that other buildings are not so close as to shut off sunlight and fresh air, and that space for play is sufficient. The home site should not be near buildings used for industries that create unhealthy or odorous conditions. In the house itself careful attention should be paid to proper plumbing, ventilation, and heating.

Disinfection.—A *disinfectant* is an agent capable of destroying disease germs. It is a germicide. A disinfectant thus has a definite purpose and should be distinguished from an antiseptic and a *deodorant.* A deodorant is an agent which merely destroys offensive odors. It may or may not be a disinfectant or an antiseptic. Disinfection, to be effective, must be carried out with the strictest attention to minute details. It has been well said that "there can be no partial disinfection of infectious material; either its infectious power is destroyed or it is not. In the latter case there is failure to disinfect." Merely to remove an odor or to stop for a while the growth of germs does not disinfect. Disinfection kills germs.

It should always be kept in mind that sunlight is an excellent disinfectant. Aside from this, the methods of disinfection most commonly used may be classed as *thermal* and *chemical.* Thermal means pertaining to heat. Fire is of course the most effective thermal disinfectant, since it oxidizes all organic matter. Where the use of fire as a disinfectant would result in the destruction of valuable property, such as expensive clothing and hangings, steam is often used. Steam at 240 degrees Fahrenheit is said to kill very quickly even the most resistant spores as well as ordinary germs. Dry heat is not so penetrating and hence not so effective as moist heat, and should be used only when the articles disinfected would be injured by moisture or by chemicals.

In the use of the chemical method, formaldehyde is regarded as one of the best disinfectants. It may be used in a gaseous or a liquid state. Clothing, rugs and curtains are quickly sterilized when exposed to its action. Chloride of lime is one of the cheapest and best disinfectants. It should contain at least 35 per cent

of available chlorine. In ordinary disinfecting it is used in a weak solution of one part of chloride of lime to 1000 parts of water.

Antiseptics are substances that stop or check the growth of bacteria but do not necessarily kill them. All germicides are antiseptics, but not all antiseptics are germicides. Antiseptic solutions are frequently used to cleanse objects to reduce dangers of infection. When used as lotions, or body washes, or as gargles, antiseptics must often be kept very weak to avoid injuring delicate body cells. This lessens their effect on germs. A simple gargle of salt and water, which is cleansing and stimulating, is more effective than most antiseptic solutions for the throat.

Many dangerous forms of bacteria accumulate in living rooms, schoolrooms, theaters, halls and churches where many people gather. These germs are often in the dust and are breathed in when the dust is disturbed. Ordinary sweeping, while it gathers up dirt, causes germ-laden dust to float about the room and finally to settle on furniture and hangings. Dusting with a dry cloth simply stirs up the dust again. It is best, therefore, to dust with a cloth dampened with water, light oil, or some antiseptic which will catch and hold the dust particles.

Wherever possible, cleaning of rugs, carpets and hangings should be done with a vacuum cleaner. In a vacuum cleaner the dust is drawn into a bag or container by means of a fan, usually run by an electric motor. The frequent cleaning of floors, seats, and hangings in places of assembly does much to prevent the spread of contagious diseases.

SUMMARY

Good health enables people to work well and to enjoy life.

There are numerous causes of loss of health. The presence of disease germs in the body is one of the most common causes.

Disease germs may be bacteria or protozoa. They are more often transmitted directly from person to person than by objects.

The paths of infection are through the mouth, the nose and breaks in the skin.

The strongest natural defense of the body against disease germs is the work of the white corpuscles.

Immunity from a particular disease may be natural or acquired. It is natural when inherited, and acquired when it results from having had the disease or from having had some preventive treatment.

Sanitation treats of methods of making our surroundings healthful.

Fact and Thought Questions

1. Discuss the importance of health.
2. Why is keeping physically fit an aid in avoiding contagion?
3. Mention errors in diet.
4. Name several diseases caused by bacteria.
5. What defenses do our bodies erect against disease?
6. Is there any danger in the entrance of just a very few disease germs into the body?
7. Name diseases caused by protozoa.
8. What is meant by natural immunity?
9. What is meant by acquired immunity?
10. What is meant by sanitation?
11. Describe sanitary methods of sweeping and dusting.
12. Name some of the effects of disease.
13. Define: (a) vaccination, (b) inoculation, (c) serum.

Projects

1. Make a list of precautions that should be taken to avoid disease.
2. Describe the sanitary equipment of a well-arranged dwelling house.

Outdoor Observation

1. Observe and list unsanitary conditions around buildings and in open fields and suggest remedies.

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CHAPTER XXXVII

HOW TO KEEP WELL

Our health is a matter of concern not only to ourselves and our home folks but to our community and to the nation. The prosperity, the strength and the happiness of the nation are materially affected by the health of its citizens.

As population grows it becomes more difficult to guard against disease. Some unhealthy person, through carelessness or indifference, may make many others sick. One unsanitary condition may cause an epidemic to sweep like an attacking army through a community.

For the good of all, our local and national governments and other public agencies, more and more, are coming to our aid to safeguard our water supply, to control the disposal of waste matter, to keep our food supply pure, and to guard us from disease. It is a matter of good citizenship to coöperate loyally with the government in observing health regulations.

One of the most significant and important characteristics of the present age is the great effort made for the conservation and lengthening of human life by the prevention of disease. In accordance with the old adage, "An ounce of prevention is worth a pound of cure," there is a growing tendency for families, schools, business firms, and other associations to employ physicians for the purpose of preventing as well as curing disease. A great health movement is extending over the world, in which the preventive methods in dealing with disease are gradually being recognized.

Among the steps taken are the control of germs and harmful parasitic organisms; the provision for an abundance of fresh air and pure water; plenty of exercise; the insistence on the sale of clean milk, approved meat, and pure foods of all kinds; medical inspection and the employment of trained nurses in the schools; adequate attention to the disposal of sewage; greater emphasis on industrial hygiene; the world-wide movement against the use of

alcohol and other narcotics; and the establishment of societies, as well as the passing of laws, to encourage and enforce other desirable health reforms.

In all of these plans, the objects are to spread knowledge of the principles governing the proper care and use of the human body, and to make proper provision for wholesome surroundings. On these things depend the preservation of health, efficiency, and the prolongation of life.

In early times, personal hygiene and home sanitation were sufficient, but with the growth of large cities, and the increase in intercourse and trade between all countries, public hygiene and sanitation have become necessary in order to preserve the general health.

The control of bacterial diseases is of prime importance. The surest control is to quarantine those sick with communicable diseases. Although the unwashed hand is probably the most frequent means of distributing bacteria, there are other active agents, among which are flies, vermin of various kinds, and house pets. Occasionally it happens that a person, apparently well, becomes a carrier of disease. Nearly everyone has heard of Typhoid Mary. She was a domestic cook and, wherever she worked, cases of typhoid fever would develop in the family. On examination, it was found that she was a carrier of typhoid germs although not suffering from the disease.

That the theory of infection from contact is becoming popularly accepted is indicated by the introduction of sanitary drinking fountains, individual towels, liquid soap and other hygienic appliances into schools, hotels, and other public places.

Information in regard to avoiding infection from animals, like rats, mosquitoes, and certain parasitic worms, is quite generally available. The hookworm in the south of our own country and in many sections of the world, is one of the most numerous parasitic worms. It attaches itself to the small intestine, seriously weakening its victim by sucking the blood from the capillaries. The work of the Rockefeller Sanitary Commission for eradication of the hookworm is a notable illustration of the efforts being made for the cure and prevention of disease.

Air Supply.—Air is the first requisite of life. Without it, even with plenty of water and food, adequate light, and suitable temperature, we can live only a very short time. You have undoubtedly noticed that it is impossible to hold your breath long without great discomfort. Unless you resume breathing you will soon become unconscious. Your blood will lose its bright red color and death will quickly ensue.

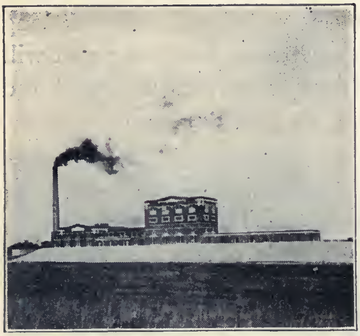
National Tuberculosis Association.

FRESH AIR IS THE FIRST REQUISITE IN THE CURE OF TUBERCULOSIS

Good ventilation requires an adequate amount of fresh air continually kept in motion and having a proper degree of humidity. The widespread use of sleeping porches, and roof playgrounds in crowded cities, and the efforts to secure as much outdoor life as possible, mark one phase of the world movement for the prevention of disease.

Water Supply.—The fact that water makes up more than one-half the weight of our bodies, and that we are constantly drinking it to replace that which has been excreted,

is sufficient reason for a pure supply. Pure water contains no disease-producing germs.



Brown Brothers.
A Filtration Plant to Purify Water

Each year there are in the United States hundreds of thousands of cases of typhoid fever, many of which have been traced to the use of water containing disease germs. In places where the water has been freed from germs, the per cent of deaths from typhoid has been greatly lowered. This is a good illustration of the power of man to rid himself of a parasitic disease by controlling his surroundings. When one suspects that water contains disease germs, he should not drink it until it has been boiled for some time.

Milk Supply.—To people living on farms and deriving their milk from their own cows, the problem of milk supply seems simple. By keeping healthy cows in clean, well-lighted surroundings, providing them with pure water and food, observing habits of personal cleanliness in milking, cooling the milk properly, and keeping it in sanitary places, the family is always sure of having plenty of pure milk.

Brown Brothers.
Interior of a Filtration Plant

The problem is not so simple in communities where families must depend on milk dealers. Even in small communities, epidemics of typhoid fever, diphtheria, and other diseases have been caused by the lack of cleanliness on the part of milkmen. The problem becomes many times more complicated in a great city where the daily supply comes from thousands of dairies located in widely-separated places. In all well-governed cities, boards

of health enforce laws that will insure the delivery of milk of approved quality.

Pasteurization.—*Pasteurization* is the process by which harmful bacteria in milk are destroyed by heating, without changing its taste or injuring its nutritive value and its digestibility. It is named after Pasteur, a great French chemist, who invented the process. Pasteurization is accomplished by heating the milk to a temperature not over 170° Fahrenheit for about twenty minutes. Milk to be used by infants should always be pasteurized. In sections where pasteurization has been practiced, there has invariably been a decrease in sickness and deaths from intestinal diseases which are caused by germs.

Experiment to Show the Nature and Effects of Pasteurization. Put a half-pint of fresh, raw milk into a pint bottle. In a beaker pasteurize a half-pint of the same quality of milk by heating it to 160 degrees for 15 minutes. Put the pasteurized milk into a pint bottle. Set both bottles aside in a cold place for 24 hours. Mount a drop from each bottle on a glass slide. Examine them under the microscope. What is the difference in the milk from the two bottles? What do you conclude about pasteurization?

Other Food Supplies.—Large cities have public markets where poultry, fresh vegetables direct from gardens, and foods of many kinds may be bought each day. Great care should be taken to make sure that all articles of food are free from germs of disease. Some cities have a food inspection division under the direction of the Board of Health, whose duties include inspection of food of every kind.

Sewage.—The disposal of waste is one of the great sanitary problems of every large community. Unless removed far from its source, or purified by some chemical process, it becomes a breeding place for germs of disease, as well as an unpleasant factor in the neighborhood. The method for sewage disposal best adapted to a given locality can be determined only by a careful consideration of all the factors and conditions involved.

Proper Clothing.—The wearing of clean clothes of the right kind is important to one's health. Wool, because it is loosely

woven and holds much air, is a poor conductor of heat and thus retains the warmth of the body. It is worn in winter to protect against too sudden changes of temperature and the colds which result from them. Cotton, linen, and silk conduct heat away from the body easily and so are good for summer wear.

Industrial Hygiene.—Industrial hygiene refers to the movement for providing more healthful surroundings for those who labor in factories, and for installing safety devices to protect those who work where there is danger of injury. The importance of this movement can readily be understood when it is borne in mind that there are in this country many millions of wage earners who spend from one-third to one-half of their lives in their places of occupation, generally within doors. Many thousands of wage earners are killed, and many more thousands are wounded by industrial accidents each year, and there are millions of cases of illness among industrial workers.

Of course all the ills and disasters that befall wage earners cannot justly be said to be due to their occupations, but a large number are. Laws requiring factory sanitation, limiting the number of hours per day of required work, and forbidding the employment of children have been passed by many states, and, where they are enforced, are an effective means of reducing injury and illness.

Brown Brothers.

EXAMINING EYES AND EARS TO GUARD AGAINST TROUBLE

School Hygiene.—Too much attention cannot be given during school life to learning the rules of health and to forming health habits. In order to give value to the teaching, the rules taught should be constantly practiced.

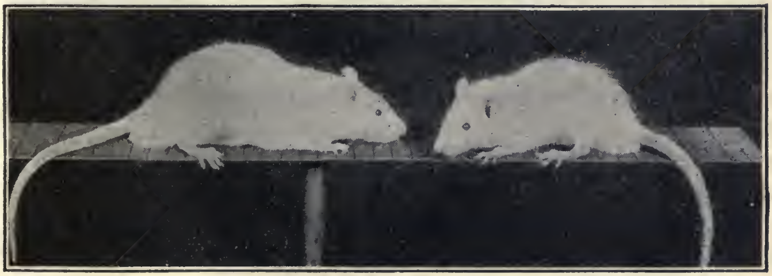
Medical inspection in many cities has shown that a very large number of children have one or more of the following disorders: defective teeth, defective hearing or sight, tuberculosis of some part of the body, adenoids or enlarged tonsils, enlarged neck

glands, spinal curvature or other deformities of posture, malnutrition, organic or functional heart disease, and various nervous disorders. These conditions warrant the movement to extend the scope of school hygiene, and indicate plainly the great importance of preventing and correcting physical defects.

Attention should be given by school authorities to proper heating, lighting, and ventilation, and to every condition that affects the health of children. Medical and hygienic supervision of schools should be welcomed as one of the greatest agents that aid in the prevention of loss of health and efficiency of youth, through the early discovery of disease.

The Nose and Throat.—It is generally recognized that the germs of many diseases, such as tuberculosis, pneumonia, colds, measles, and scarlet fever, gain entrance to the body through the nose and throat. For this reason it is important that these organs be properly cared for. Nature has provided them with two main defenses against germs, tiny hairs in the lining of the nasal passages and mucous secretions in both nose and throat to catch the germs and hold them. These defenses are, however, not always effective, and it is therefore wise to spray both nose and throat with an antiseptic solution once or twice a day when such diseases are prevalent.

Tonsils.—Healthy tonsils are harmless, but when diseased they harbor germs which lead to sickness. Diseased tonsils are a source of danger and should be removed.



Battle Creek Sanitarium.

MILK IS MORE NEARLY A COMPLETE FOOD THAN ANY OTHER

These rats were given exactly the same care and food, except that the one on the left had milk added to his diet. Note the difference in their size. This illustrates the value of the experiment in medical science

Malnutrition.—Malnutrition is a term used to indicate lack of proper nourishment of the body, and is often a forerunner of tuberculosis and other diseases. It may be due to a faulty diet, irregularity of meals, or lack of care in the selection and preparation of food.

Tuberculosis Among School Children.—Although the fight against tuberculosis has brought about remarkable results among adults during the last twenty-five years, statistics show that

Brown Brothers.

NOURISHING FOOD AND FRESH AIR PROMOTE HEALTH

the ravages of the disease are still great among children. Some of the best authorities now believe that the infection is taken by very young children. Children have tuberculosis more often in their bones than in their lungs, and thousands are crippled in consequence. Schools should coöperate in stamping out this disease among children. The cure for children, as for adults, is open air. Open air schools should be conducted for infected children.

Dangers to Health from Alcohol.—It is a well-established fact that people who indulge in the use of alcoholic drink show less resistance to infectious diseases than those who do not use it. Alcohol paralyzes the white blood corpuscles which are the strongest guardians against infection that the body possesses.

Laboratory and medical evidence shows that alcohol, if taken regularly even in moderate quantities, lowers the power to resist disease, and produces conditions in the kidneys and brain that favor the development of Bright's disease and insanity.

Child Welfare.—One of the most promising factors tending toward the prolongation of human life is the great interest now taken in child welfare. Organizations like the Child Health Organization of America are doing remarkable work in solving problems connected with the care of children. It is estimated that forty per cent of the children of our country need more or less care of a public nature. Large numbers of children die each year from common disorders, due largely to the fact that the parents are not familiar with, or do not heed, the requirements of hygiene and sanitation.

Advice and assistance are needed in regard to the care of children not yet of school age. The most practical solution yet suggested for the aid of this class of children is the employment of community nurses by local authorities. In the interest of health there can be no doubt that a staff of such workers would render invaluable service.

Modern Surgery.—The first important application of the knowledge of germs in the field of surgery was made by Lord Lister. Previous to Lister's time serious infection frequently followed an operation, due to germs entering the wound both during and after the operation. By constant application of germ-killing solutions, Lister did much to free surgery of infection. His method was known as *antiseptic* surgery. Its effectiveness depended upon killing all germ life in and around the wound.

Experience with antiseptic surgery led naturally to *aseptic* surgery, a step in advance. This consists of operation under perfectly sanitary conditions. Bandages, instruments, clothes, and hands are made absolutely free from germs. No antiseptic

solutions are used, for no germs are present. This is an advantage over antiseptic surgery for germ-killing solutions irritate wounds and retard their healing.

Health Institutions.—There are many institutions of a semi-public character that are doing remarkable work for the conservation of health. Among those in this country are the Rockefeller Institute for Medical Research in New York City, and the Nutrition Research Laboratory in Boston. The discovery of a serum for the treatment and cure of meningitis by Dr. Simon Flexner of the Rockefeller Institute is an illustration of the great value of the work done by institutions of this kind.

The Life Extension Institute was organized to encourage the movement to prolong human life. It gives advice to its members in regard to ways of keeping well. It has a large staff of examining physicians in its head office in New York City, and has the services of more than seven thousand examining physicians throughout the United States and Canada. It provides personal physical examinations at regular intervals as a means of preventing needless suffering and premature death.

Necessity for Coöperation.—In order to accomplish desirable results, it is necessary for all the forces working toward a proposed end to pull together. These forces may be individual or public. Individual hygiene depends on the effort of each citizen to observe the requirements of cleanliness. Public hygiene and sanitation depend on the efficiency of the government in providing and maintaining surroundings that are in every way conducive to health, but especially in guarding against the spreading of contagious diseases. In the latter work there is much encouragement in the words of Pasteur: *"It is within the power of man to rid himself of every parasitic disease."*

The city, the state, and the nation all have their boards of health. They divide the important duties of health protection and together work toward a common end—the betterment of the health of the people.

City boards of health have charge of municipal hygiene and sanitation. Among the duties of such boards are the making and enforcement of regulations in regard to the removal of sewage

and garbage; the prevention of pollution of the water supply; the provisions for a pure milk supply; the abatement of nuisances, like the smoke nuisance and unnecessary noises in the streets at night; the control of insects that carry disease and of rats that transmit to man the dreaded bubonic plague; the improvement of drainage; the care of public baths, public parks, and public museums; the establishment of bacteriological laboratories and free medical service; the prevention and control of epidemics through the distribution and use of vaccines, antitoxins, serums, disinfection and quarantine; and the inspection of shops, restaurants and public buildings.

State supervision of public health becomes necessary because in rural districts there is no supervision, and because food, water and milk used in cities come largely from the country.

Among the functions of state boards of health are the regulation of child labor so that children may grow up without being weakened by the strain of factory life, the limitation of hours of labor to prevent loss of health through overwork, the requirement of sanitary conditions in factories to prevent the spread of disease, and of protective devices on machinery to safeguard workers from accidents, the enforcement of decent living conditions in tenement houses and of sanitary conditions in public buildings, and the supervision of sources of milk supply.

The Federal Government endeavors to prevent the introduction of contagious diseases from foreign countries by quarantine and by excluding diseased immigrants. It enforces the Pure Food and Drug Act, the laws regulating the inspection of meat, and the laws for the exclusion of dangerous narcotics. All these aid in conserving our national vitality.

The duties and activities of boards of health are vital to the well-being of the communities they serve. On this account it is exceedingly important that efficient and conscientious health officials shall be elected or appointed, that they shall have suitable authority and that they shall have the loyal support of other officials and of citizens in general.

Investigations, laws, inspections and penalties undoubtedly aid in the efforts to prolong life. However, the fact remains that

popular education in regard to the value of ventilation, proper preparation and use of good food, care in regard to adequate rest and to recreation in the open air, and the habit of watchfulness to prevent accidents will always be found most effective. The prevention of disease and the preservation of national health and vitality depend on the efforts of each individual citizen, who should aid just as much as possible. He should know and practice the laws of good health. As a good citizen, he should be familiar with and should carefully observe community health regulations.

SUMMARY

Great efforts are now being made to lengthen human life by the prevention of disease. This is accomplished by controlling germs and harmful parasites, by insuring fresh air, pure water, and pure foods, by medical inspection, by proper sewage disposal, by restricting the use of alcohol and narcotics, by emphasis on industrial hygiene, by restricting the employment of children, and by the enforcement of general health regulations.

The control of bacterial diseases is brought about by personal cleanliness, by quarantine of those sick with contagious diseases, by the destruction of germ-carrying animals, and by sanitary conditions, especially in public places.

The safeguarding of water and of milk supplies is emphasized because these fluids easily carry germs. Milk is often protected by pasteurization, a heating process.

Proper clothing protects health.

The health of industrial workers is increasingly protected by regulations governing hours of labor and sanitary working conditions.

The health of school children is protected by sanitary school buildings and by strict medical inspection, leading to early discovery and treatment of disease. The eyes, ears, nose, throat, and teeth are given special attention.

In modern aseptic surgery, operations are made under as nearly germless conditions as possible.

The loyal coöperation of all citizens with health officials is essential to disease prevention.

Fact and Thought Questions

1. What is meant by the conservation of health?
2. Mention some of the agents by which disease is spread.
3. State the importance of an abundance of fresh air to health.
4. What are the advantages of sleeping porches?
5. State the importance of a supply of pure water to health.
6. State the importance of great care in securing pure milk for use in the home.
7. What is meant by pasteurization?
8. Discuss the importance of sewage disposal.
9. What are the advantages of medical inspection in the schools?
10. How can you contribute to school health?
11. Why should we know and observe public health regulations?
12. Discuss the importance of industrial hygiene.

Projects

1. Test several samples of raw milk from different sources to determine their degrees of freedom from bacteria.
2. Visit a sewage disposal plant and study its workings. Write a report.
3. Find out what health organizations have authority over health conditions in your community. Prepare a brief report on their duties, responsibilities, and powers. State in brief form several health regulations it is the duty of every citizen to observe.

Outdoor Observation

On your way to and from school, note evidences of care and of neglect of the surroundings of houses and business places that affect sanitation and hygiene.

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CHAPTER XXXVIII

FIRST AID

Accidents often occur without warning. Something happens suddenly that endangers our life, or that of others. Minutes, even seconds, count. If we do not know what to do, precious time is lost. But knowing how to apply first aid steadies us, whether we have to serve ourselves or another. If we are helping another, our own sureness gives the patient confidence and self-control.

Serious accidents are common occurrences in this machine age. But even the small cuts and bruises and burns, if denied prompt and proper attention, may become serious.

Surely some day each and every one of us will face a first aid emergency, great or small. So there is a very real need for studying first aid. It enables us to meet the emergencies of everyday life and gives us the power to render great help in time of need.

An accident which requires quick action to insure safety is called an *emergency*. Every one knows that, in spite of all precautions, accidents and illnesses needing immediate attention happen daily. Few persons, however, realize how large a number of cases occur where first aid may render valuable service. In a certain lumbering district nearly five thousand accidents happened within less than six months. Casualties occur frequently wherever any number of automobiles are in use. On the public highways of the United States during a single year there were over 770,000 casualties. Even in the household many accidents occur. One accident insurance company, in a recent report, says that nearly twenty-eight per cent of the number of claims paid for accidental injuries were for injuries received in and about the household.

Doctor Agnew of Philadelphia once said: "Every surgeon knows full well that in many cases of injury the crisis is reached before the patient arrives at the hospital gate, and the lack

of instructed aid at first often turns the tables against him." Since most accidents occur when the services of a doctor are not immediately available, the importance of first aid is apparent.

Common Emergencies.—Among the most common cases needing first aid are burns, scalds, shock, bruises, sprains, strains, dislocation, fractures, wounds, nose bleed, fainting, sunstroke, frostbite, poisoning, and asphyxia.

American Museum of Safety.

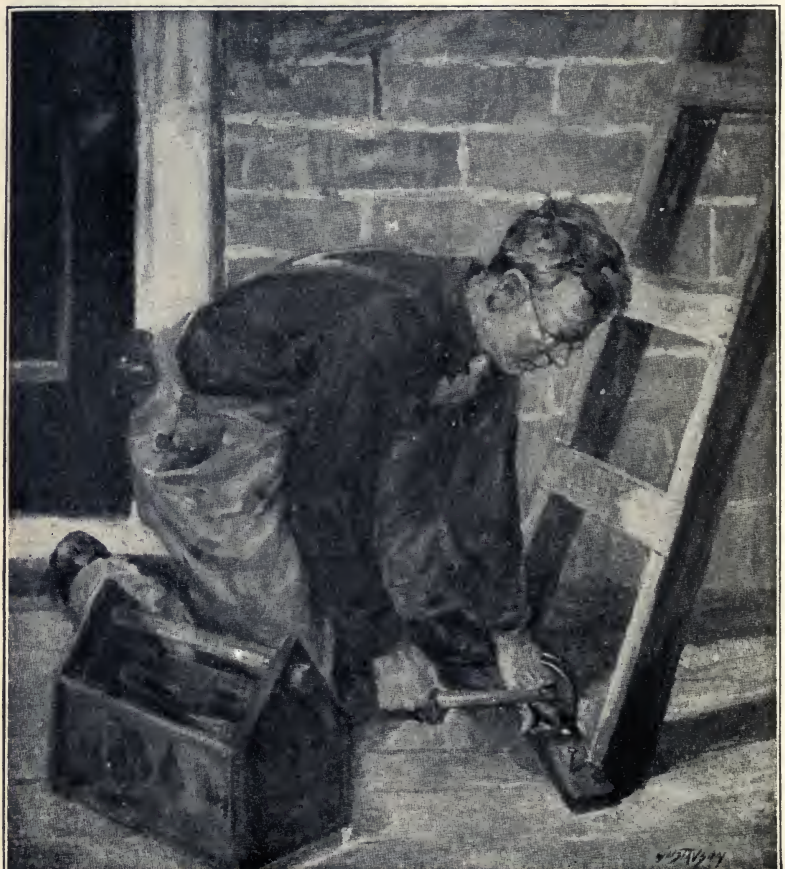
TREATING A SPRAIN

Burns and Scalds.—Burns are caused by contact with fire, hot substances or strong chemicals; and scalds by contact with steam or boiling water. These are especially dangerous with children and with elderly people. The treatment depends on the extent of the injury. If the skin is merely reddened or slightly blistered, the exclusion of air by a thin paste made with water and baking soda covered with a light bandage to hold the dressing in place is usually sufficient. If the blistering is extensive and the tissues beneath are affected, a physician should be called. Meanwhile, the burned part should be immersed in warm water, or covered with carron oil or vaseline overlaid with cloth soaked in the oil.

In case you see a person whose clothing is on fire, prompt action is necessary. Seize the nearest rug, shawl, overcoat, or other heavy woolen article, wrap it quickly around the sufferer, to smother the flames and if possible keep them from his face. If necessary, throw him to the floor and roll him over and over.

Shock.—When suddenly hurt in any way, one often feels dizzy, short of breath, and sick, and may even lose consciousness for a moment. This kind of illness is called shock. A person affected in this way should be placed on his back so that the action of his heart and his respiratory movements may be as little disturbed as possible.

Bruises.—Bruises are usually the result of falls or blows, and cause swelling of the tissues and the formation of black and blue spots, due to the escape of blood from the capillaries. There is more or less pain according to the severity of the injury. Slight bruises require no treatment. Relief from bruises that cause swelling and pain may be had by the immediate application of very hot water or of very cold water, powdered ice, arnica or witch-hazel. In case, however, there appears to be any other



New York State Automobile Alliance.

WHATEVER THE JOB, MAKE IT SAFE AGAINST ACCIDENT

injury connected with the bruise, like the breaking of a bone or the rupture of the soft internal parts, a physician should be consulted at once.

Sprains.—Sprains are bruised muscles, ligaments, and nerves about the joints. They occur when joints are turned too far or in the wrong direction, and are most common in the ankles and wrists. They often cause severe pain and swelling of the joints. Rest, and the application of very hot or very cold water, arnica or witch hazel, are usually sufficient treatment for an ordinary sprain. Severe cases should be treated by a physician.

Strains.—Strains are injuries to muscles, resulting usually from efforts to lift too heavy loads. They are most common in the muscles of the back and shoulders and in the tendons of the ankles and of the wrists. They cause stiffness, lameness, and sometimes swelling of the parts affected, together with some pain. Rest, and the application of alcohol and water, or of a linament, soon afford relief.

Dislocation.—A dislocation is a displacement of a bone at a joint. When the head of a bone slips out of its socket, the result is a dislocation. It occurs most frequently in the shoulder, but may occur in the hip, the jaw or the fingers. It is usually the result of a blow or a fall. Efforts to reduce dislocations, except in the case of the fingers, should not usually be attempted by an untrained person. A dislocated finger may be readily replaced by pulling the end straight out away from the hand. In other cases, unless the attendant has received training in the methods that should be used, a doctor should be summoned. In the meantime, until the doctor's arrival, the sufferer should be placed in a comfortable position, and cloths soaked in very hot or very cold water should be applied to the injured parts.

Fractures.—When a bone in the body is broken, the injury is called a fracture. The majority of fractures happen to the bones of the arms and legs. They may be simple or compound. In a simple fracture the skin has not been pierced by the edges of the broken bone. In cases where the skin has been pierced the fracture is said to be compound. The latter is more dangerous, because germs gain entrance into the wound through the break in

the skin and infection may take place, causing inflammation with the possibility of blood-poisoning. A doctor should be called at once for any fractured bone.

While awaiting the doctor's arrival the patient should be placed in as comfortable a position as possible. Great care should be taken in handling the injured parts, if it seems necessary to do this in changing his position, as the jagged ends of the bones may be made to injure the soft tissues. The bone should be supported on each side of the break, and a pillow or folded garment should be used to keep it in a natural position. In case of a compound fracture the wound should not be touched, owing to the danger of infection, but a soft antiseptic pad should be placed on it as soon as possible. No effort should be made to carry a patient until the broken bone is held in position by splints.

Wounds.—Wounds may be classified under three heads: incised wounds, or cuts of various depths usually made by knives or glass; torn, or lacerated, wounds in which the skin and tissues beneath are more or less torn instead of cut, usually by harsh contact with some object that tears or crushes; and punctured wounds, such as stabs and pricks made by thorns, needles, or other sharp instruments. Bullet wounds are also included in this class. Practically all wounds cause more or less bleeding, or hemorrhage.

Treatment.—Treatment differs according to the amount of hemorrhage. The blood may come from veins or from an artery. When it comes from a vein the flow is steady; when it comes from an artery the blood comes forth in jets and is of a bright red color. If there is much bleeding a doctor should be called immediately. In the meantime, pending his coming, if the hemorrhage is not severe the wound should not be touched by the hands of any one, not even by the sufferer himself, and no unsterilized cloth or other object should come in contact with it, since there is always danger of infection. Clothing about the wound should be turned back to avoid contact. Exposure to the air does not cause infection. Iodine, if available, should be used to paint all parts of the wound readily reached, and if possible a sterilized bandage should be placed on it. This will prevent infection and in most cases will also stop the hemorrhage.

In case the hemorrhage is severe, indicating injury to a large blood vessel, effort should be made to check the flow at once. Unless the vessel is large, the flow will usually be stopped by the formation of a clot. Bleeding from an artery may be checked by pressure on it at some point between the wound and the heart. In case the wound is in a limb, a handkerchief or towel tied about it, on the proper side of the cut, and twisted tight by means of a stick, will stop the bleeding. Unless the patient seems weak, the use of stimulants should be avoided until the bleeding has

Brown Brothers.

CHECKING THE FLOW OF BLOOD FROM A CUT IN THE HAND

been checked, since they increase the action of the heart and thus render it more difficult to stop the bleeding.

Nose Bleed.—Application to the back of the neck of a cloth soaked in cold water, or the placing of a small object between the gum and the upper lip, will usually check nose bleed. If this does not stop it, a solution of salt and water should be snuffed up the nose. In case all these methods fail, a doctor should be called.

Fainting.—Fainting is a common occurrence. It is caused by an insufficient supply of blood to the brain and may result from

fright, loss of blood, fatigue or poor ventilation. The face becomes pale, the lips white and the breathing rapid. The patient should be laid on his back, with his feet slightly raised and his head lowered to allow blood to flow to the brain. His clothing should be loosened, and plenty of air supplied by opening doors and windows. Cold water may be sprinkled on his face. In case a person faints in a crowd, he should immediately be removed. Recovery usually occurs in a short time.

Sunstroke.—Sunstroke is caused by exposure to great heat, generally when the air is moist. It may occur under the hot summer sun or indoors in hot and poorly ventilated kitchens, laundries, or workshops. An attack is usually preceded by pain in the head and by a feeling of oppression. The skin becomes hot, the pulse full and rapid, and the breathing labored. The patient may become unconscious. Sunstroke is very dangerous and requires the presence of a doctor as soon as possible. The treatment consists in reducing the body temperature. Pending the arrival of the doctor, cold water or ice should be applied to the face, neck, and chest of the sufferer.

Heat Exhaustion.—Heat exhaustion is not the same condition as sunstroke, although due to the same cause. It often begins with dizziness, or nausea and vomiting, followed by great depression. The patient does not become absolutely unconscious, and does not suffer as much as one afflicted with sunstroke. He should be removed to a cool place, the clothing loosened and cold applications applied until the arrival of the doctor.

Frost Bite and Freezing.—The parts of the body most commonly affected by frost bite are the nose, ears, fingers and toes. The frozen part should be rubbed with snow or cold water until it regains its normal temperature.

In case of freezing, the patient seems like a dead person. He should be treated in a cold room. The warmth of the body should gradually be restored by rubbing the limbs toward the body and by the application of cloths soaked at first in cold water, and gradually in that which is less and less cold until warm water can be used with safety. A warm drink, such as tea or coffee, may be given as soon as the sufferer can swallow. He should not be

exposed to heat of any kind until his circulation has been well restored in a cool room.

Poisoning.—Whenever it is known that a poison has been swallowed, a doctor should be called at once. While waiting for him, an emetic, which is a substance that will cause vomiting, should be taken. A tablespoonful of mustard or of salt in a cup of warm water is a good emetic. Vomiting may also be caused by running the finger down the throat.

Foreign Bodies in the Eye, Ear or Throat.—Whenever a cinder or small particle of dust gets beneath the lid of the eye it irritates the delicate membrane and often causes much discomfort and pain. In such cases, the eye should never be rubbed. If the eye is closed tears will often wash out the foreign substance. In case this is not effective, relief will sometimes come from blowing the nose on the side opposite the eye affected, taking care to draw the upper lid over the lower one several times before blowing.

If this method fails ask a friend to assist. Having pressed the lower lid down, if the foreign substance is seen allow him to brush it off with the corner of a clean handkerchief. If relief is not obtained, have him examine the upper lid. This is not so easy. Seated in a chair with head bent backward, allow the assistant, standing behind, to place a match or a wooden toothpick across the upper lid a little above its edge. By turning the lid up and back he can brush off the substance, if visible, with the handkerchief. If all efforts fail, the services of a doctor should be sought.

Foreign bodies that lodge in the ear should be removed by a physician. Sharp instruments should not be put into the ear since there is danger of injuring the drum and thus causing deafness. In removing wax from the opening, a wet towel placed over the finger should be used.

Foreign bodies in the throat are likely to cause suffocation by blocking the windpipe. Children are most liable to suffer in this respect. Thumping on the back will often afford relief. If this does not suffice, the sufferer should be turned upside down and effort made to dislodge the foreign object. A doctor should be called immediately.

SUMMARY

An unforseen occurrence, requiring quick action to insure safety, is called an emergency.

The importance of first aid is often great in emergencies.

First aid is most often needed in cases of burns, scalds, shock, bruises, sprains, strains, dislocation, fracture, wounds, nose bleed, fainting, sunstroke, frost bite, and poisoning.

FACT AND THOUGHT QUESTIONS

1. Name several common household emergencies within your experience; several outdoor emergencies.
2. State how you have treated yourself in a simple emergency.
3. Describe your treatment of another in a simple emergency.
4. Name three types of wounds, and the treatment for each.
5. Name an emergency in which it would be advisable to administer first aid even before sending for a doctor.
6. What is the difference in treatment for a cut and for a severe bruise?
7. What is a fracture? State the difference between a simple and a compound fracture. Why is the latter more dangerous?
8. Why is it dangerous to keep poisons in a bathroom medicine cabinet?
9. Describe your treatment for a severe burn.
10. You are aroused from sleep by a small insect within the ear. How would you get it out?
11. Suppose you sprain an ankle seriously while tramping alone far from help. What would you do?
12. Is it "good citizenship" to know how to administer first aid? Why?
13. What ordinary supplies should be kept in a household for first aid use?
14. State the first aid treatment that should be given in case of a small cut or scratch on the finger. Give a reason for your answer.

PROJECTS

1. In a class demonstration, show how to revive a person who has fainted. (A member of the class may act as the patient.)
2. In a class demonstration, show what first aid to give in case of a fracture.
   (A member of the class may act as the patient.)

OUTDOOR OBSERVATION

Observe and note, over an extended period, accidents, however slight, that occur outdoors. Decide on the best first aid treatment in each case.

REFERENCES

Emergencies .... *Gulick*
First Aid.................................... *American Red Cross Book*

GENERAL THOUGHT QUESTIONS FOR DISCUSSION AND REVIEW

GROUP V

1. Suggest some health values of "clean up" campaigns.
2. Tell why being "a skilled workman" is largely a matter of bodily control.
3. What is the effect of alcohol on the heart action? State briefly how the use of alcohol as a beverage may affect (a) the endurance of an athlete, (b) the digestion of protein, (c) the sharpness or acuteness of the special senses.
4. Why do mountain climbers breathe oxygen from tanks when at great altitudes?
5. Why do we use ice boxes?
6. Answer the following with one or two words or statements:
    - (a) Give two characteristics of good indoor air, aside from any reference to oxygen or carbon dioxide.
    - (b) Give two reasons why it is important to masticate food thoroughly.
    - (c) Which food nutrient is capable of supplying the most heat and energy?
    - (d) What function of the skin makes it important to keep the skin clean?
7. Why are many children "always hungry"?
8. Explain the value of a sun parlor in a home.
9. What is Nature's way of giving one a good complexion?
10. How would you perform an experiment to determine the relative humidity in the air? Make a labeled sketch of the apparatus used.
11. How would the lack of any bacteria in the world affect our lives?
12. Why do dogs pant when heated?
13. What is meant by a runner getting "his second wind"?
14. If one were limited to milk or to bread as a steady diet, which would be better?
15. Why not play tennis after eating a hearty meal?
16. If impurities drain into the top of a well is it safe to drink water drawn from the bottom where a pure spring feeds the well? Why?
17. Describe an experiment to show the presence of bacteria in air or in water. Tell what was used, what was done, what happened, how the control experiment was made, and your conclusions.

18. State whether you think the following statements are true or false, giving your reasons for your opinion in each case:
    (a) All bacteria are harmful.
    (b) A person living in a frigid zone requires more fat food than one living in the torrid zone.
19. Give the hygienic importance of each of the following:
    (a) Bathing the skin, (b) chewing the food well, (c) drinking plenty of water, (d) cleaning the teeth every day, (e) eating plenty of fruits and vegetables.
20. Why do foods containing water spoil more quickly than thoroughly dried foods?
21. Of what value to health is street sprinkling?
22. With regard to fire:
    (a) Mention a fire hazard that may exist in the home; the school; some public meeting building. Tell what means should be taken to eliminate each hazard.
    (b) Suggest things to remember if caught in a burning building.
    (c) Tell what to do if a person's clothing catches fire.
    (d) Give directions for first aid treatment of burns.
23. State two physiological reasons why a young person should not use tobacco in any form.
24. Why is it "good citizenship" to observe local health regulations, and to safeguard one's own health?
25. Does the color of clothes affect health or comfort? How?
26. A housekeeper sprinkles a floor before using a broom but not before using a vacuum cleaner. Why?
27. Why is an injury to the spine so often a serious matter?
28. Food is a fuel and body builder. Keeping this statement in mind, tell (a) why summer and winter diets should be different, (b) why a balanced diet is best for most people, (c) why foods containing large amounts of water are expensive, (d) why wastes should be regularly eliminated from the body, (e) why plenty of exercise and fresh air are needed every day.

    Complete the statements in the next three questions.
29. Our sense of smell protects our health by ——.
30. Regular daily exercise is better than a longer period of exercise on Saturdays only, because ——.
31. If in doubt of the purity of one's drinking water, one should ——.
32. By aid of a labeled drawing or blackboard sketch of a model, demonstrate the proper ventilation of a room.
    (a) By referring to your diagram, explain how the model was used to show good and bad methods of ventilation. Use arrows to show directions of air currents.
    (b) Tell what happened in the experiments.

(c) State your conclusions based on the experiments.

(d) Show how a practical use of these conclusions may be made by you in your own sleeping room.

33. Why is deep breathing better than shallow breathing?

34. Name five steps taken by the body in getting energy out of an apple.

35. Name some of the values of a balanced diet.

36. (a) What is the effect of alcohol on the white of an egg?

(b) How does alcohol affect the digestive juices?

(c) How does alcohol affect the walls of the arteries?

(d) How does alcohol affect the white corpuscles?

(e) Give one good reason (not mentioned in your answers to a, b, c, or d) why athletic coaches prohibit the use of alcohol by athletes during training, and one good reason why many athletic trainers discharge from training squads athletes found using tobacco.

37. (a) Explain how an ordinary liquid thermometer works.

(b) Make a drawing of a thermometer tube, indicating in their proper positions by degrees the freezing and boiling temperatures of water and the best average temperature for a living room.

(c) Name two liquids commonly used in making thermometers.

38. (a) Mention three ways by which heat is transferred from one place to another.

(b) By which method is the heat in your schoolroom chiefly distributed? Give reasons for your answer.

(c) Explain fully with the aid of a diagram why a room is usually warmest near the ceiling.

E. L. Crandall.

FLOWERING DOGWOOD
One of our most beautiful native trees.

CHAPTER XXXIX

THE GREEN PLANT

Among the wonders of the world are the plant food-factories that exist all about us in countless number. Driven by the power of the sun, the green plants of garden, field and orchard work incessantly during the growing season that we may live.

From air, water and soil, they gather their supplies. In their green leaf laboratories they manufacture food starch or sugar and the proteins that are eaten by man and animals. These they store away in leaf, stem, seed and root.

From green plants we get the fruit and vegetables and nuts we eat, and the grains we grind into meal or flour. They furnish certain medicines as well, and aid us in other ways. Our knowledge of our surroundings should surely include the life and working processes of plants.

In a general way plants may be divided into two classes—those which produce seeds and those which do not. In the seed-producing class are included trees like the elm, maple, and hickory; shrubs like the raspberry, currant, and barberry; and herbs like peppermint, sage, and daisy. Among the plants that do not produce seeds are ferns, mosses, seaweeds, and various forms of fungi, such as mushrooms and puff balls.

The Green Plant.—In the green foliage plants with which we are most familiar, whether tree, shrub or herb, the principal parts are the leaf, stem, and root. These are the organs by which the plant relates itself to the external world, and by which it carries on its life processes. All these parts are composed of cells.

To demonstrate that the plant is composed of cells, its tissues should be examined by the aid of the compound microscope. By mounting and examining cross sections of a young bean seedling, the inner scales of an onion, or some other growing part, the cell structure may be observed. The cell wall and the protoplasm, which consists of the nucleus and the cytoplasm, may be

plainly seen. The cell wall is the very thin covering which encloses the protoplasm and separates the cell from its fellow cells. The cytoplasm is the liquid nutritive part of the cell, and the nucleus is the very minute, slightly denser part. The nucleus is the vital part and is the source of reproduction.

An interesting demonstration is to observe, by the aid of the compound microscope, the circulation of the protoplasm in a living cell of a water plant called *Elodea.*

The Cell, the Unit of Structure and Function.—The smallest plant is a single cell containing all the parts necessary for the manifestation of life. All large plants are made up of many, often millions, of cells, so related to one another as to form a single organism. Since all the parts of this organism are composed of cells similar in structure and in function, the cell may be considered the unit of both structure and function.

Cell Division.—Cells increase by division. Under normal conditions when a cell reaches its full growth a nucleus forms in each half. This is followed by a division of the cell body into two parts and by the formation of a cell wall which separates the two new cells. In the same way all cells divide, and thus the organism grows in size.

CELLS OF ELODEA
The arrows indicate the movement of the protoplasm.

Comparison of the Needs of Plants and Animals.—Animals and plants need nearly the same conditions in order to exist. Like animals, plants must have food, moisture, air, and heat. Plants will not survive without light. Animals can live without light as long as the other conditions are present, but it should not be forgotten that after a time there would be no food if there were no light. So light also, in the final analysis, is necessary for the maintenance of animals.

Functions of Plants.—Since plants need food, air, and moisture, it follows that they must have the means of securing and using these substances. Hence they perform the same functions as animals to secure them, together with the additional function of food-making. Under favorable conditions these processes are

carried on through the medium of the stems, leaves, roots, and seeds.

Sensation and Motion.—Although the plant has not the specialized senses that animals possess, nevertheless it is sensitive to external influences, especially to light, heat, and moisture. Notice how leaves gradually turn toward the light when not facing it, how the tiny roots reach out toward water, and how susceptible plants are to lack of heat. Some plants are so sensitive that they wilt and droop when merely touched. The ability of plants to respond to stimuli is limited; nevertheless, they possess sensation and the power to move. By the exercise of these functions they adjust themselves to their surroundings.

Respiration.—Respiration is an absolutely necessary function in plants as well as in animals. Upon it depends the oxidation of food, the release of energy, and, in short, the very life of the plant itself.

In respiration oxygen from the air passes into the intercellular spaces of the leaves through the small openings, called *stomata,* on the lower surface. Then it is absorbed through the cell membranes and enters into the sap, which transports it to the different parts of the plant body where it comes into contact with digested food and oxidizes it. In this process energy is released and carbon dioxide and water are produced, as in animals. These products are returned to the leaves where they are excreted. Although the leaf is considered the main organ of respiration, as a matter of fact this process occurs in all living parts of plants.

Some oxygen also enters the plant through the root hairs and through the *lenticels,* or minute openings in the bark. A little carbon dioxide is likewise thrown off by these organs.

In these ways oxygen is carried to all the living cells of plants, and the energy needed by the cells is supplied through the oxidation of nutrients that are stored there. Thus we see that respiration serves the same purpose in plants as in man and animals.

One reason why the farmer tills the soil thoroughly before he sows the seeds is that seeds must have oxygen in order to germinate. By stirring the soil the farmer introduces air into it, and, under proper conditions of warmth and moisture, the oxygen

in the air unites with the food stored in the seed, producing energy to promote growth. The embryo, or baby plant within the seed, will not develop unless supplied with moisture, oxygen, and heat as well as food.

Experiment to Show Oxidation in Living Things.—We have learned that oxidation produces heat and carbon dioxide. Here is an experiment to show that plants as well as animals give off heat and carbon dioxide as a result of the oxidation that goes on in their bodies.

Read a thermometer and then put it into a jar of sprouting seeds. Put the cover on the jar. Wrap the jar in some material to prevent the escape of heat and leave it for two or three days in a place of uniform temperature. At the end of this time notice any change in the temperature in the jar. Place a small amount of lime water in a small container in the jar. Does the lime water turn milky? Does this experiment indicate that germinating seeds give off heat and carbon dioxide? Hold a thermometer in your hand and notice any change in the temperature recorded. Breathe into lime water. Do you conclude that oxidation goes on in living things?

Absorption and Food-storing.—A green plant has a function which an animal does not have, that of making and storing food within itself. From the soil the roots of the plant absorb food materials in solution, which pass through the plant until they reach the leaves, where carbon dioxide is absorbed from the air and combined with them to make food. This food is stored in the roots, stems, seeds, and leaves. A part of this stored food is later digested and used by the plant for carrying on its life processes. The part stored in the seed is used to nourish the embryo, or baby plant in the seed, until it can grow food for itself. Healthy plants, however, make and store more food than they can use. They are the food-makers of the world.

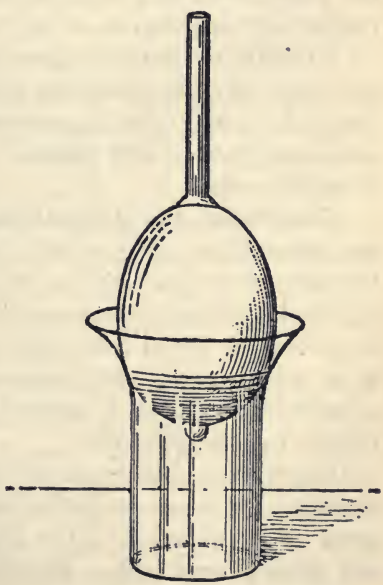
Osmosis.—You will remember that food in a liquid state is absorbed into the blood through the membranes of the stomach and intestines, and that oxygen is absorbed from the air into the blood through the membranes of the lungs and carbon dioxide is given off from the blood to the air. Plants, too, absorb and give

off liquids and gases through their membranes. They absorb food materials in solution through their root membranes into the sap. The digested food is absorbed from the sap through cell walls into the cells. Through the membranes of certain leaf cells plants absorb and give off oxygen and carbon dioxide. In every case, a fluid, either a liquid or a gas, passes through a membrane into another fluid.

Strange as it may seem, even the most powerful microscopes fail to reveal any holes or pores in plant or animal membranes. Yet the fact that liquids and gases pass through them readily proves that openings of some sort must be there, since it is impossible to explain this passage of liquid or gas in any other way. This process of absorption or diffusion of a fluid substance, liquid or gas, through a membrane without visible pores into another fluid substance is called *osmosis*.

Osmosis, then, may be defined as *the mixing of liquids or of gases, separated by an animal or a plant membrane, by passing through the membrane.* The greater flow is always from the less dense to the more dense substance.

Experiments to Show Principle of Osmosis.—Tie a piece of animal membrane, taken from the bladder or wall of the intestine of an animal, over one end of a glass tube from one to three feet long. Partly fill the tube with molasses and place it on a frame so that the covered end stands in a dish of pure water. After leaving the apparatus for some time, it will be found that the liquid in the tube has risen, while the water in the dish has lowered. Water must



EXPERIMENT TO SHOW OSMOSIS
The water passes through the membrane of the egg.

have passed through the membrane into the molasses which is a thicker solution.

If preferable, an egg may be used to illustrate osmosis. Fasten one end of a small open glass tube, 8 to 12 inches in length, to the small end of the egg, by allowing melted wax to harden around the place where the end of the tube touches the shell. Then, after passing a hat pin or wire through the tube, puncture the shell and the membrane of the small end of the egg. Remove the shell from the lining membrane at the larger end of the egg over an area of about ¾ of an inch in diameter. Place the egg in a small tumbler of water with the exposed membrane in the water. After two hours examine and observe what has happened.

Experiment to Show the Upward Course of Soil Water in a Root.—Place a growing plant, a carrot for example, in a vessel containing red ink, in such a way that the lower part of the root dips into the fluid. Leave the plant until a red color shows in the leaves, indicating that the fluid has been absorbed by osmosis through the membranes of the root hairs.

Digestion.—Before a green plant can use the food which it has made to build new cells and to supply energy, it must first digest the food. This is accomplished largely in the leaves by a special substance called *diastase,* an enzyme which changes starch to soluble sugar.

Circulation and Assimilation.—Digested food flows in solution through the veins in the plant and is taken up by the cells throughout the plant by the process of osmosis. The movement of this liquid may be compared to blood circulation, as it is a movement of liquid conveying food material in the plant body to its various parts. As it passes into the cells, the digested food is assimilated, that is, it is made a part of the growing plant and is used to build new cells.

Excretion.—Plants excrete water vapor, oxygen, and carbon dioxide. The leaves give off water vapor much as the human skin gives off perspiration. They also give off oxygen. Both leaves and stems excrete carbon dioxide in respiration.

Reproduction.—Plants, as well as animals, reproduce their kind. Reproduction is carried on through flowers or blossoms.

When particles of a fine yellow dust, called pollen, are carried from one flower to another, or from one part of a flower to another part, by means of the wind or by certain insects, they cause the egg cells of the flower receiving the pollen to grow into fertile seeds. These seeds are then released by the plant, and under favorable conditions will develop and become mature plants.

Leaves.—Leaves are the chief agents by means of which the plant relates itself to light and air. A typical green leaf consists of three parts, the *blade,* the *petiole,* or leaf stalk, and a pair of leaf-like organs called *stipules* situated at the base of the leaf stalk. The blade is the broad, flat part of the leaf, the part best adapted to receive the largest amount of light.

If you observe leaves carefully you will see that they have a framework composed of fibers that penetrate the whole inner surface and provide a place of attachment for the more delicate parts. These fibers, or ribs, are called *veins.* They are the channels through which fluid circulates to every part of the leaf. In some leaves there is one larger fiber or vein called the *midrib* which separates each leaf into two similar halves.

Although these veins are arranged in many ways, there are two general types. In one type the veins are parallel or nearly so, and the leaves are called *parallel-veined.* The elm is an example. In the other type they are branched so that they form a network and are called *netted-veined* leaves. In netted-veined leaves the two most common kinds are the feather-like, known as the *pinnate* type, and the palm-like, known as the *palmate* type. The leaf of the ash tree is an example of the pinnate type, and the geranium leaf is an example of the palmate type.

Simple and Compound Leaves.—Leaves are classed as simple or compound. In simple leaves the blade consists of a single, flat, undivided surface. In compound leaves there are several separate blade-like parts, or leaflets, borne on the same midrib or the same petiole. Most compound leaves are netted-veined. Nearly all leaves of *dicotyledonous* plants—plants whose seeds have two *cotyledons,* or seed leaves,—are netted-veined. With few exceptions, *monocotyledonous* plants—plants whose seeds have one cotyledon—bear parallel-veined leaves.

Types of Leaves

A. Elm.
B. Willow.
C. Oak.
D. Holly.
E. Linden.
F. Magnolia.
G. Horse Chestnut.
H. Butternut.
I. Hemlock.
J. Ash.
K. Locust.
L. Ailanthus.

The important physiological functions of leaves are *photosynthesis, transpiration, respiration, digestion* and *assimilation.*

Photosynthesis, or Food-making.—The very great service rendered by leaves is the making of carbohydrate food. This is done only by the green parts of plants, principally the leaves, in the light of the sun. Although apparently the first visible food product made is starch, experts have demonstrated that the very first product manufactured is sugar, which in most cases is quickly changed to starch and stored in various parts of the plant. This very interesting fact should always be remembered. All the sugar in the world is made by green leaves.

Food Materials.—The materials from which carbohydrate food is made are water and carbon dioxide. Water is obtained from the soil, and carbon dioxide from the air. Other materials needed for the manufacture of other kinds of food necessary to the plant are brought into the plant in solution in water through the medium of the root hairs, tiny threadlike branches of the roots. In this way the plant obtains compounds that contain nitrogen and sulphur. These are combined in the cells with the carbohydrates, and thus the protein food needed for growth and development is provided. Fats are formed by chemical changes in the starches and sugars in plants. They are found stored mainly in nuts, seeds, and grains.

The Main Requirements for the Manufacture of Carbohydrates.—The five main requirements for the manufacture of carbohydrates are: a living green plant, the presence of carbon dioxide, some degree of heat, the presence of sunlight shining on the plant, the presence of water, and certain chemical changes. The process takes place not only in the leaves but also in any green part of the plant. The air contains the carbon dioxide. The rays of the sun furnish the energy. The chemical changes take place in the green cells when the two compounds, water and carbon dioxide, are broken up into the elements of which they are composed and are recombined into new substances by a series of steps not fully understood. In the process oxygen is released. The immediate product of this process is grape sugar. In most plants this is changed to starch in the leaves very soon after its formation.

Experiments to Show that Starch is Made in Green Leaves in the Presence of Light.—The following experiment shows the necessity of light for photosynthesis.

Experiment to Show Photosynthesis
Starch is made only in the exposed part of a green leaf.

Cover with tinfoil or a cork about one-eighth of the surface of both sides of the middle part of a green leaf growing on a plant. Place the plant in bright sunlight with this leaf arranged so that the upper side will get full illumination. Near the close of the day, cut off the leaf. Remove the cover of tinfoil or cork, boil the leaf in water to soften the tissue, and then place it in alcohol for a day to remove the coloring matter. Finally, test with iodine for starch. Observe in which part the presence of starch is indicated, and state your conclusion as to the importance of light in the making of starch.

The necessity of light for photosynthesis may also be shown in the following way: Place a growing green plant, provided with proper heat and moisture, in a dark room, and after a few hours remove several leaves and test them for starch. After this, place the plant in the sunlight for a few hours, and then remove several leaves and test for starch as before. State your conclusion.

Comparison of Respiration with Photosynthesis.—Respiration is a breaking-down process; photosynthesis is a building-up process.

In respiration oxygen is taken in by the plant, and carbon dioxide excreted; in photosynthesis carbon dioxide is taken in by the plant, and oxygen is excreted.

In respiration carbon dioxide is formed as the result of a chemical change; in photosynthesis starch and sugar are made as a result of a chemical change.

Respiration occurs in plants whether green or colorless; photosynthesis occurs only in the green parts of plants.

Respiration occurs in the dark and in sunlight; photosynthesis occurs only under the influence of sunlight.

In respiration, energy is released; in photosynthesis energy is stored.

Transpiration.—Transpiration is a term given to the evaporation of water from living leaves. It is similar to perspiration from the human skin and may be called a form of excretion. Transpiration is a process of much importance to plants.

Beneficial Effects of Transpiration.—The process of transpiration renders service to the plant in at least two ways. First, it makes possible the continued ascent of water in the plant, which is necessary to convey raw food material in solution to the cells of the leaves and stems. Second, as evaporation has a cooling effect, it may under certain weather conditions prevent the killing of the leaves by too much heat.

Harmful Effect of Transpiration.—Excessive transpiration destroys the life of plants. If water evaporates more rapidly than it is replaced from the soil, the leaves soon wilt, and unless the supply is restored the plant dies. This explains why it is necessary to thoroughly water plants in hot, dry weather. Leaves are protected in several ways against this loss of water: by a waxy coating, by the growth of hairs on their surface, by the development of a thick-walled epidermis and by other means.

Economic Importance of Leaves.—Leaves are of great economic importance. Many of them, such as the leaves of the cabbage and lettuce plants, supply man with food. Leaves, especially those of grasses, help feed all grazing animals. The leaves of the tea plant serve to make a beverage. Leaves, such as sage and wintergreen, supply flavorings. Others, such as peppermint, boneset, wormwood and eucalyptus, serve as medicines. One of the greatest services rendered by leaves, however, is that of keeping the air pure by absorbing far more carbon dioxide than they give off and giving out far more oxygen than they use. Thus man and all other living things are dependent on green leaves for the supply of oxygen needed to sustain life.

SUMMARY

Plants are divided into two classes, those which produce seeds and those which do not.

The leaf, stem, and root are the principal parts of a plant. Like animals, plants are composed of cells and perform the functions of respiration, digestion, circulation, assimilation, excretion, and reproduction. They also manufacture food by a process called photosynthesis.

Respiration in plants serves the same purpose as in animals. It oxidizes food and releases energy.

Digestion in plants is a process by which starch made in the leaves is changed into soluble sugar.

Assimilation is the taking up of digested food by the cells of a plant for the building of new cells.

Excretion in plants is the throwing off of water vapor and oxygen by the leaves, and of carbon dioxide by the leaves and stems.

Leaves are the main organs by which the plant carries on photosynthesis, respiration, digestion and excretion.

There are two general types of leaves, netted-veined and parallel-veined.

Leaves are simple or compound. Simple leaves consist of a single flat surface. Compound leaves have several leaflets on the same leaf stalk.

The evaporation of water from living leaves is called transpiration. By this process water is excreted from the plant. It is an important process but if excessive may prove harmful.

Leaves provide food for man and animals, aid in purifying the air, and some are used in the preparation of medicines.

Fact and Thought Questions

1. Name some green plants growing in your neighborhood that you can use for food.
2. Explain why everything you eat really comes from plant food.
3. Could there be any cities if there were no country districts? Why?
4. Name two general classes into which plants are divided.
5. Mention the principal parts of a green plant.

6. Give the composition and the characteristics of protoplasm.
7. Name the life processes of plants.
8. Describe the structure of a typical leaf.
9. Mention the physiological functions of green leaves.
10. Why do we "trim back" many transplanted plants?
11. What are the harmful effects of transpiration?
12. Name several things you can do to help plants manufacture food.
13. Mention the raw materials from which carbohydrate food is manufactured.
14. Give the beneficial effects of transpiration.
15. Describe respiration in leaves and state why it is necessary.
16. Compare respiration with photosynthesis.

Projects

1. Make a list of the trees you can recognize at sight, telling how you identify each.
2. Visit a farm or a market and make a list of all the food plants or their products that may be used for food.

Outdoor Observation

1. Observe various types of leaves. Collect specimens and classify them.
2. Note the response of leaves of garden plants when watered in dry weather.

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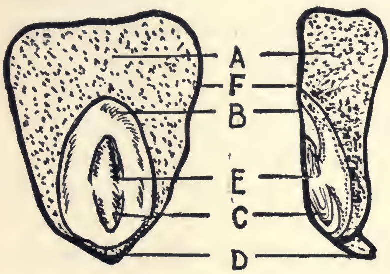
CHAPTER XL

SEEDS AND HOW THEY GROW

One of the most wonderful processes of nature is the storing of new plant life in tiny seeds, by means of which new growth is assured to meet our needs. Without seeds to sow, fertile soil and moisture would be of little value to us. Seeds, however, are so small that we can transport them in countless numbers and so plant them in the right soil to produce new harvests for our food.

Compressed in these tiny seeds are the richest of the green plant's food products. These nourish the new plants in their first stages. Thus it is easy to see why nuts and grain are so nutritious. Let us take a look into the structure of these seeds where the tiny new growth is started on its way.

Structure of Seeds.—The most important part of a mature seed is the *embryo,* the tiny plant within the seed. This usually is composed of three parts, the *hypocotyl,* the *epicotyl* and the *cotyledon* or *cotyledons.* The hypocotyl is the part of the embryo below the cotyledon, or seed leaf, which develops into the first root and stem. The epicotyl, or plumule, is the part of the embryo above the cotyledon which develops into the stem and true leaf. The cotyledon performs different functions in different plants. It may act as a storehouse of food for the embryo, as an organ for the manufacture of food, as an organ for the digestion and absorption of food, or may perform several of these functions. In certain seeds, such as corn and wheat, food is not stored in the cotyledons

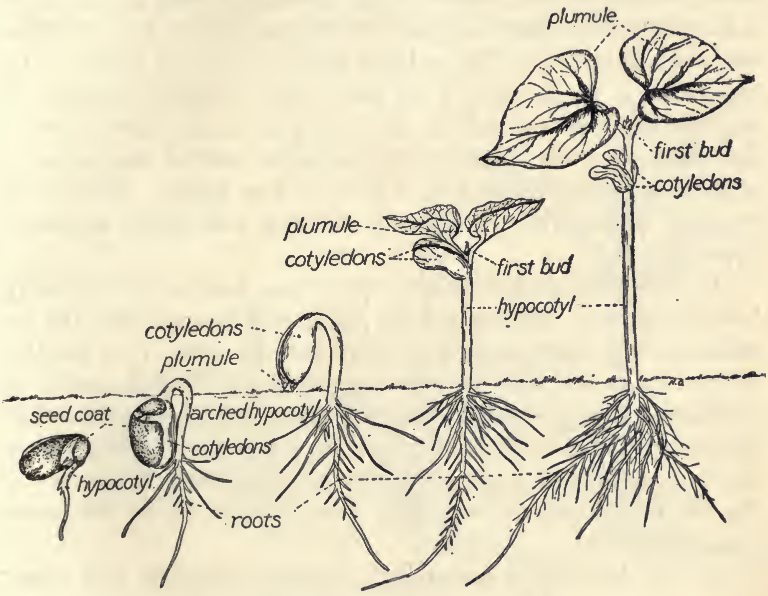


SECTION OF CORN GRAIN

A. Endosperm.
B. Cotyledon.
C. Hypocotyl.
D. Point of attachment to the parent plant.
E. Embryo.
F. Testa.

of the embryo, but in the seed outside the embryo. Food stored in this way is called *endosperm.*

Other parts of the seed are: the *micropyle,* a tiny opening in the seed through which the pollen grains grow into the ovule, or egg cell, and through which the hypocotyl comes out; the *hilum,* a scar which indicates where the seed was attached to the parent plant; and the *integument,* the outer covering or seed coat. Often the integument has two layers, the outer being hard or tough and



THE GROWTH OF THE BEAN SEEDLING

the inner soft and thin. In such cases the outer layer is called the *testa.*

Types of Seeds.—The bean and the corn grain are two types of seeds well worth study. The bean is a dicotyledonous seed and the corn grain a monocotyledonous seed. Study of these will show that, while they differ in structure, they carry on the same life processes, effect the same purpose, and serve mankind in the same way.

The Bean.—In studying a bean, observe the surface markings on the testa, or outer layer of the seed coat, the hilum, or scar, on one side, the micropyle, or tiny opening in the hilum, and the integument, or thin inner coat. Notice that the bean is composed mainly of two parts of equal size and appearance. These are the cotyledons, or seed leaves, in which is stored the food for the use of the young plant, called a *seedling,* as soon as it emerges from the seed. It is said to be a seedling as long as it derives its food from the cotyledons, or until it has developed roots and leaves to aid in the manufacture of food. Taking apart the two cotyledons, observe a tiny body. The rod-like portion which is joined to the cotyledons is the hypocotyl, the lower part of which will push its way through the seed coat at the micropyle as the embryo grows, and form the root. Attached to the upper end of the hypocotyl observe a minute stem with a pair of tiny leaves. This is the plumule, which will develop into the stem and leaves above the hypocotyl.

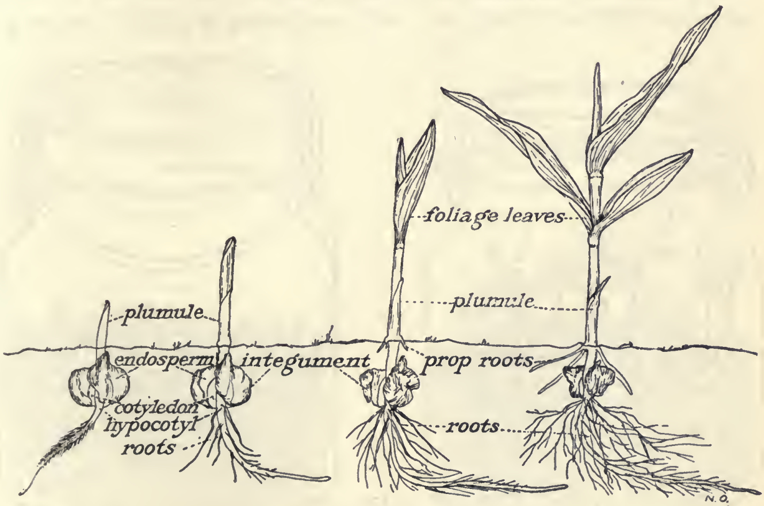
In the process of germination the stem part of the hypocotyl becomes curved, forming a loop, and grows upward into the air, while the root part grows downward into the soil. It is the loop which breaks the way through the soil and as it grows pulls the cotyledons from the soil, thus enabling the delicate plumule which lies between the cotyledons to get above gıound without injury. Once above ground it grows rapidly, feeding upon the nutrient in the cotyledons, which soon shrivel and fall away as the young leaves develop.

As the bean plant matures the plumule develops into a pair of broad leaves to carry on photosynthesis, the hypocotyl becomes a sturdy supporting stem, and the root develops tiny, hairlike branches which take moisture and nourishment from the soil by osmosis and pass them on to the rest of the plant. The seedling has now become a fully developed bean plant.

The Corn.—In the study of the corn grain, or kernel, observe that it is somewhat wedge-shaped in form with a shallow groove upon one side, underneath the surface of which the embryo is visible in outline. Notice the point of attachment to the cob at the lower end of the grain and the slight scar at

the top, where the corn "silk" was once attached. The hilum and the micropyle, although present as in the bean, are covered and so cannot be seen. Cutting off a thin longitudinal section from the face of a well-soaked grain at right angles to its flat broad sides, observe in the part remaining the cotyledon as well as the hypocotyl and the epicotyl; also observe the endosperm that surrounds the embryo.

Taking another well-soaked grain, make a longitudinal section directly through the middle of the broad part of the grain at right angles to its narrow sides, and again identify the cotyledon, the



Growth of the Corn Seedling

hypocotyl, the epicotyl and the endosperm. By soaking the cut sections in a solution of iodine, the various parts may more easily be recognized. Iodine colors the starch dark blue or black and stains the embryo yellow or orange.

In the process of germination, the hypocotyl, protected by a cap, pushes down into the soil and the root develops. The plumule meanwhile pushes its pointed end up through the soil and soon unrolls its small leaves. The seedling thus becomes able to make its own food.

The following table gives a comparison of the bean and the corn seeds.

Bean	*Corn*
Has two cotyledons containing stored food	Has one cotyledon containing no stored food
No endosperm	Endosperm (food for the tiny plant)
Testa, hilum and micropyle	Testa; hilum and micropyle not visible
Epicotyl, large	Epicotyl, smaller than in bean
Fruit, a pod containing several seeds	Fruit, a grain having but one seed

Experiments with Seeds.—

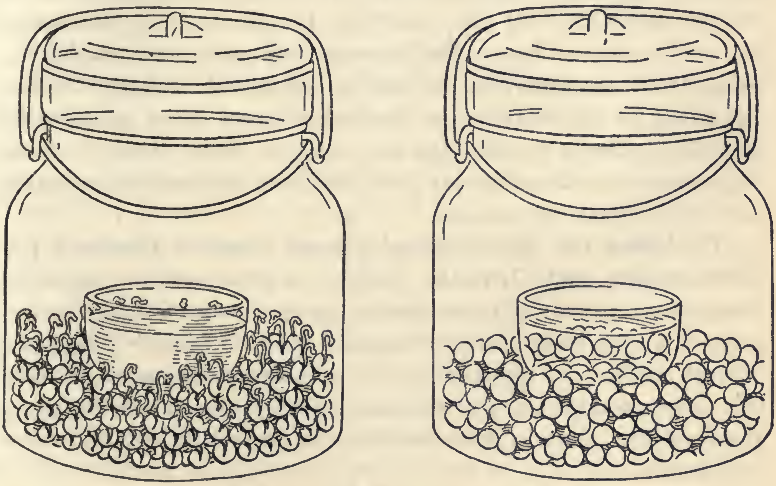
To Show the Necessity of Oxygen in the Air for Germination.—Use two fruit jars, each containing a small amount of

EXPERIMENT TO SHOW THE NECESSITY OF OXYGEN FOR GERMINATION

earth. In one jar place a small quantity of pea seeds that have been well soaked in water. Close the jar tightly. In the other jar place the same quantity of soaked seeds and leave the jar uncovered. If the jars are kept for several days in a warm atmosphere it will be noticed that the seeds in the open jar germinate quickly and grow rapidly into healthy, strong plants, while the seeds in the covered jar fail to continue to develop after a short time. By placing a lighted candle in the covered jar it will be

seen that there is no oxygen present, since the candle will at once cease to burn. Hence we conclude that the oxygen was consumed in the process of germination. The covered jar serves as a check, or control.

To Show the Necessity of Heat and Moisture for Germination.—Place a number of pea seeds in each of three jars. Soak the seeds in one jar and leave it in a warm place. It serves as a check, or control. Soak the seeds in the second jar and leave it in a cold place. Keep the seeds in the third jar dry and leave it in a warm place. Examine the seeds periodically for a week or



Experiment to Show that Carbon Dioxide is Produced During Germination

ten days. In which jars do the seeds germinate? What do you conclude concerning the necessity of heat and moisture for germination?

A fourth jar, prepared like the first but left in a dark place, can be used to prove that light is not necessary for the germination of seeds, though it is needed for the later development of plants.

To Show That Carbon Dioxide Is Produced During Germination.—Using two jars, place a quantity of soaked seeds

in one and dry seeds in the other. Also place in each jar a small cup of lime water and cover both jars tightly. After a short time it will be noticed that the lime water assumes a milky appearance in the first jar where the seeds have germinated, and that there is no such change in the water in the second jar where germination has not occurred. Hence we conclude that germinating seeds give off carbon dioxide. This also proves that the seeds used the oxygen, since carbon dioxide is a result of oxidation.

To Show That Heat Is Given Off by Seeds During Germination.—Place a thermometer in each of two jars, in one of which perfect seeds have all the conditions for germination: moisture, air, and moderate heat. In the other, let one of the conditions, such as providing moisture by soaking the seeds, be absent. Notice the effect on the mercury in the thermometer after germination has taken place in the first jar, and compare with the effect on the thermometer in the other jar in which there has been no germination. State your conclusion.

To Prove the Necessity of Stored Food in the Seed for Germination and Growth.—Taking several perfect grains of corn, place them in a jar having proper conditions of moisture, air, and heat for germination. In a second jar, place several grains of corn with the endosperm removed, having the same conditions of moisture, heat, and air as those in the first jar. After a few days observe the result and state your conclusion.

To Prove the Digestion of Starch During the Germination of a Seed.—Using Fehling's solution, determine whether or not grape sugar is present in several corn seeds before germination. After germination apply the same test to the seeds and draw your conclusion. Try the same procedure with other kinds of seeds.

Conclusions.—After performing these experiments you will know from observation that seeds, in order to insure germination, must have nutrient material, and proper conditions of air, moisture, and heat. They will not, however, continue to grow vigorously without sunlight.

Selecting and Testing Seeds.—Many seeds lose their ability to sprout when kept too long. Other seeds may fail to germinate for other reasons. Consequently, many farmers and gardeners select and test seeds carefully before planting them.

Here is a simple way to test seeds. Place several layers of blotting paper in a dish. Scatter the seeds to be tested over the paper. Cover the dish to reduce evaporation and set it in a warm place. Examine the seeds at intervals until sure that all have had a chance to germinate. Then find the per cent of the total seeds that have sprouted. By testing seeds from several other sources and comparing the results, the best seeds for planting can be determined.

Experiments with Roots and Stems.—

To Show the Response of Roots to Gravity.—That roots will grow in a downward direction may be shown by planting clover or other small seeds in a small glass container, and by tipping it at different angles from time to time as the roots develop. In whatever position it is placed, at a slant or even upside down, the roots will gradually turn downward. This is caused by the attraction of the earth, known as gravity. This response to gravity is positive when objects tend toward the center of the earth and negative when they tend away from it. It is positive with respect to roots, but negative with respect to stems. Stems which naturally grow upward cannot be made to grow downward.

To Show the Response of Roots to Moisture.—The effect of the presence of moisture near roots may be illustrated by planting soaked seeds near the center of the top of a glass box filled with sawdust which has been moistened in one end of the box and not moistened in the other end. The tiny roots will grow downward and turn towards the moist part. This tendency is very beneficial to plant growth, especially in sections where a lack of sufficient moisture prevails. This attraction of roots toward moisture accounts for the fact that drains sometimes become clogged with roots of willows, grasses, and other plants.

To Show the Response of Stems and Leaves to Light.—Place small growing plants in a window, well exposed to the sun and notice that the stems and leaves tend to turn so as to secure

the largest possible exposure of leaves to the light. Turn the plants several times at intervals of a few days and observe what occurs in each instance. What conclusion do you draw?

Importance of Seeds to Man.—You undoubtedly realize that only through seeds do most plants reproduce themselves. Have you ever considered how important seeds are to man? The principal source of the food of the world is from nutrients stored in seeds. Without seeds most of our food plants would vanish and all animal life would be endangered in consequence. The carbohydrates, sugar and starch, so necessary to life, made in such a wonderful manner by the green leaves, are stored chiefly in seeds. Likewise the protein food nutrients formed in the plants are stored largely in seeds. Without protein in food, protoplasm, the physical basis of life, cannot be produced. Without carbohydrates, energy in sufficient quantity would not be available. Seeds store and conserve both these food substances for man.

SUMMARY

The most essential part of the seed is the embryo, usually composed of three parts—hypocotyl, epicotyl, or plumule, and cotyledon or cotyledons.

Experiments show that seeds in order to germinate must have food, air, moisture, and a favorable temperature. After germination, the young plants must also have sunlight to insure vigorous growth.

The importance of seeds to man is apparent when it is borne in mind that the principal source of the food of the world is obtained from nutrients stored in seeds.

Fact and Thought Questions

1. Describe the structure of the bean seed.
2. Describe the structure of the corn grain.
3. Why do many plants fail to grow in winter?
4. Describe an experiment to show the necessity of oxygen for germination of seeds.
5. Describe an experiment to show that heat is given off by seeds during germination.
6. Describe the structure of the embryo in a seed.

7. State the conditions necessary for germination of seeds.
8. Describe an experiment to show that carbon dioxide is produced during germination of seeds.
9. Describe an experiment to show the necessity of stored food in seeds to insure germination.
10. Name and describe the parts of a seed.
11. How does nature scatter seeds?
12. Why do deep-rooted plants endure drought better than shallow-rooted ones?
13. Why is occasional thorough watering of potted plants better than frequent slight watering?
14. Why do transplanted plants often wilt and then revive?
15. At what stage of its development can a plant do without light?
16. Discuss the economic importance of seeds and their products.

Projects

1. Make a collection of various kinds of seeds of economic importance. Place each kind in a separate small bottle and label.
2. Plant and cultivate a row of beans in your home garden. Record in your notebook the progress of the growth of the plants, and the number of quarts in the crop.

Outdoor Observation

1. On your walks, collect as many different kinds of seeds as possible. Observe what provisions Nature makes to aid in their protection until ripe and to aid in their distribution.
2. Observe seedlings of different kinds of plants at different stages. Record your findings.

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CHAPTER XLI

FORESTS AND WHAT THEY GIVE US

Trees are the oldest and largest living things on our earth today. Undoubtedly some of the giant redwoods of California were growing before the Christian Era. During their lifetime nations have risen to power and then have disappeared and our great modern civilization has developed. Even shade trees about our homes may have lived through the whole development of transportation from the saddle horse and stage coach to automobile and airplane.

Trees are among our most valued helpers. They give us fruit and nuts and sugar for food. They supply paper for our books and for our newspapers. They furnish lumber and furniture for our homes and fuel to warm us. They shade our streets, and purify the air. They protect our soil and add to its fertility. In forests, the rich spongy soil made by the trees holds back flood waters, and releases them gradually to our streams and springs. Our health and prosperity depend in part on the proper care of our tree growth.

A forest is a large tract of woodland, an extensive community of trees. The farm wood lot, "the woods" as it is commonly called, is really a small forest. The ground covered by a forest is called the forest floor.

Importance of Forests.—Forests are important because they prevent floods, help to maintain a uniform flow of streams, retard erosion, or the wearing away of soil, and provide homes and shelter for numerous kinds of wild birds and animals, as well as many products useful to man.

Prevention of Floods.—Beneath the trees in the forest is the forest floor, a spongy layer of rich soil composed mainly of humus. The roots of the trees form a network binding the soil together, the shade of their branches keeps the soil from drying up, and their constant shedding of twigs, branches, and leaves keeps it rich in

organic material. This forest floor serves as a giant sponge during heavy rains, holding back the water which otherwise would flow rapidly into the streams causing floods and the wearing away of valuable soil. Moreover, by enabling the water to pass off slowly, the forest floor causes a more uniform flow in the streams, and in this way often prevents low water as well as floods.

Prevention of Erosion.—We have all noticed that sloping fields and dirt roads are soon cut into by a flow of water during

New York State Museum.

A Fine Forest Growth

a rainstorm and that much soil is carried away. Rivers and streams are constantly wearing down their banks and carrying off the soil. Trees growing on their banks render a great service by binding the soil together with their roots and so largely prevent this destructive action of water. In hilly country without forests this erosion may continue until only barren rock is left, and the

land is made useless. The deltas of great rivers, like the Mississippi and the Nile, are made up largely of soil brought down by the streams from the land through which they flow.

Forest Aid in Making Soil.—The leaves and branches that fall on the forest floor decay and become mixed with rock particles, thus constantly forming new soil and improving that already made. In consequence, forest soil does not require the use of fertilizers, for nature has already enriched it.

Forest Products.—The most important product of the forest is lumber, needed for the building of our houses, the laying of our railroads, and for countless other uses. Oak, elm, Douglas fir, birch, maple, walnut, mahogany, and pine are among the trees which yield material for the making of furniture, for the ornamentation of rooms, and for many other purposes.

The forest supplies us with most of the fuel we burn. From the living forest trees we get our wood, and from the buried remains of long dead forests we get our coal. We get paper and rayon from wood pulp, which comes from trees, chiefly the conifers, the poplars, and the basswood. Tar, turpentine, and resin are derived from the pines and the hemlocks. In several sections sugar and syrup are obtained in large quantity by boiling the sap of the maple. The forest also supplies us with many valuable medicines, such as quinine and camphor.

Preservation of the Forests.—As forests are of so great importance to the welfare of man, it is essential to the development of a country that they be preserved. To this end, it becomes necessary for the government to protect them from their enemies, among which are man himself, fire, insects, and fungi.

Man.—Since the value of forests to a country is so apparent, one would think that man would be reluctant to waste them. Such, however, is not the case. In his desire to accumulate wealth he recklessly cuts and uses the trees for various purposes without replacing them with new growth. Seldom does he stop to think that he is rapidly exhausting the supply of lumber, as well as exposing the land to the ravages of flood, drought, and erosion. He is the most dangerous enemy of the forests. He not only cuts them, but he is needlessly wasteful in doing so. Parts of the

trunks that might be useful are left to rot where they fall, and much good material is wasted in the sawmill.

Fire.—Fire due to man's carelessness causes the destruction of many forest trees annually. Sometimes a camper in the forest in the dry season of the year thoughtlessly throws away a burning match or a cigar, forgetting how easily dry leaves and twigs ignite. So many fires were caused by sparks from the engines of passing trains in the Adirondack forest preserve that New York state passed a law requiring locomotives to use oil instead of coal

New York State Conservation Commission.

WHAT REMAINS AFTER A FOREST FIRE

while going through this section. In addition to these preventable fires, many woods fires are caused by lightning. Fires in the forest not only destroy the trees, but often attack the forest floor and burn the humus, in this way injuring the soil, destroying the germinating seeds and so preventing the growth of new trees.

Insects.—Insects are the source of much damage to forests, especially in localities where the insect-eating birds have been killed or driven away by sportsmen. Insects injure trees by eating

the green leaves, thus destroying their means of making food, or by sucking the sap through the leaves and bark, which takes away food already made. Decaying branches, dead trees, and stumps are often the breeding places of insects that later may attack living trees. Among the insects most harmful to trees are the elm leaf beetle, the tussock moth, the gypsy moth and the brown tail moth.

Fungi.—Trees, like all other living things, are subject to diseases, the most common of which are caused by fungi. Fungi are low forms of plant life unable to make food, since they possess no green parts. They develop from spores which are so very light and small that they are easily carried by the movement of the air from tree to tree. Falling on a growing part where the surface has been broken, they germinate, and their thread-like structures grow into the substance of the tree, feed on its tissues, and soon exhaust its vitality. One of the most harmful fungi is the white pine blister rust, which has caused the destruction of millions of dollars worth of white pine trees. Other fungi harmful to trees are the common white and yellow wood-rots.

Forestry.—The object of forestry is the preservation and cultivation of existing forests, and the restoration of forests that have been destroyed. Forestry is now regarded as a vocation and many men well trained in this line are rendering excellent service to their country. Through their work they help to insure a constant supply of lumber for the country's needs, and a more regular flow of water in streams and rivers. Their reforesting also protects the land against destructive erosion and is invaluable in the preservation of our native wild life.

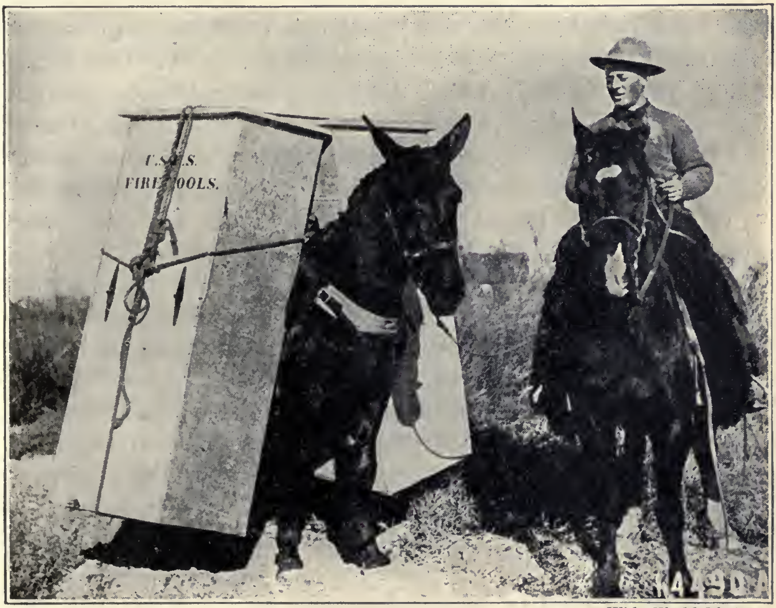
The value of forestry has been recognized for centuries by some of the leading countries of Europe. Germany and Switzerland were the first nations to try to preserve their forests by insisting on judicious cutting and on reforestation. No nation can afford to destroy its forests; on the contrary, it should try in every way to conserve them.

Our own country was somewhat slow in recognizing the necessity of caring for her forests. Not until 1875 did the United States take any real interest in their preservation. However, when

the very great value of our forests was realized, the government took hold of the matter, and we now have a well-organized Forest Service, as a division of the Department of Agriculture.

Our National Forests.—Few people realize the size and extent of our national forests. In 1891 laws were enacted permitting the President to set aside forest lands as public reservations. Accordingly, President Harrison established such reservations covering more than 18,000,000 acres. President Cleveland added 22,000,000 acres. Under Theodore Roosevelt millions of acres more were set aside. Under the Weeks law 16,000,000 acres were added, most of which are in the southern states and New England. It is now estimated that our national forests cover about 185,000,000 acres. They are located largely in the western and southern states, in New England, Alaska and Porto Rico.

All these forests are protected by the Department of Agriculture, whose purpose is to allow their use but not their abuse by



Wide World Photos.

A FOREST RANGER
Ready to fight the flames.

the people of the country. Consequently lumbering, though carried on, is limited so that the new growth will replace what is taken. As a further result of this protection the forest preserves furnish pasturage for millions of heads of livestock, protect about one-third of the sources of water power in the country, and furnish a vacation land for hundreds of thousands of people every year.

Protection.—The protection of the forests against the devastating agencies of fire, insects, tree diseases, and unlawful trespass are among the duties of the Forest Service. Of these duties fire protection and fire prevention are by far the most important.

Control of Forest Fires.—Although great effort is made to prevent the starting of fires in the forests, even with the best precautions they do occur frequently. To control and put out these fires the Forest Service has formed an organization which may be compared to the Minute Man organization of our colonial forefathers. When a combination of weather conditions occurs, like high wind, little humidity, and high temperature, an alarm is sent to all the forest rangers to be especially watchful. This watch is kept from tall towers built on high points of land, or from airplanes. In these ways extensive views are had in every direction over the forest areas. Whenever telltale smoke or haze is located, a warning is sent to the local chief of the Forest Service.

When a fire is discovered the forest guards and the forest rangers form the first line of defense in the fight, and if it proves a large fire every available man is sent to assist. All labor in saw mills and lumber camps ceases, so that every man may engage in the fight. All the men from the villages and settlements near-by aid in the fight, and as a last resort the United States Army is called upon to overcome the fires. If the flames cannot be suppressed by beating or smothering, efforts are made to keep the fire from spreading. This is done by surrounding the fire or by cutting off its advance with a trench, with a fire line, which is a belt of burnt-over land, or with a firebreak, a belt of cleared or plowed land.

Safeguarding the Water Supply.—The protection of the regions that supply water, called watersheds, is closely connected

with the problem of public health. It is the duty of the Forest Service to insist that sanitary conditions prevail in all camps on the watersheds in order to guard against the pollution of the water supply of the people who live in the cities and towns in the valleys.

Reforestation.—The fact that our forests are disappearing, in spite of all efforts to preserve them, makes it necessary that steps be taken by the government to prevent this disaster. Reforestation is the remedy. In regard to this Col. Henry S. Graves, when Chief of the United States Forest Service, said: "The question of forest renewal and growth is one that can no longer be ignored. It is not only of interest to the public, but it is of vital concern to the owners of woodlands. I would have little concern about the amount of timber used if we were growing new trees in place of the old."

Care of Trees.—All persons are more or less interested in trees. To few people, however, does it occur that the same conditions or factors are necessary to the growth and development of trees as are necessary to the growth and development of man. They know that food, light, air, water and heat are needful for their own growth and development, and that their health would not be normal if any of these conditions were permanently lacking. The same is true of trees, as of all plant life.

Different species of trees demand different kinds of climate. Trees which grow naturally in the temperate zone are not able to endure the hot sun of the equatorial latitudes, nor will they live in the polar regions. Some of the largest known trees in the world are found in the temperate zone, for example, the redwood trees of California. There is a line in the colder regions of the earth called the timber line beyond which trees cease to grow, owing to the cold.

Trees, like all forms of organic life, must have food in order to carry on their life processes. Like other plants, they make their own food, obtaining the raw materials from the air and the soil. From the air they secure carbon dioxide and, from the soil, water and food nutrients. These, under favorable conditions,

are chemically combined in the plant and made into carbohydrates, proteins, and fats.

Trees perform the same life processes as other plants, animals, and man. Having made their food and stored it in their stems,

Brown Brothers.

A GRACEFUL AMERICAN ELM

roots, leaves and seeds, they digest, absorb, and distribute it in their bodies where it is assimilated and used to promote growth. They also excrete waste, and reproduce their kind.

Giant Trees.—In different parts of the world there are wonderful giant-like trees of great age. Among them are the baobab tree of Africa, the banyan of India, the eucalyptus of Australia, and the great Sequoias of the United States.

Naturally we are interested in the big trees of our own country. The Sequoias are the largest living things. They are members of the pine family. Once spread over a large part of the ancient world, the Sequoias are now making their last stand on the Sierras in California. Like the bisons they seem to be destined to annihilation. They are already confined to isolated groves of which there are now about thirty, numbering from one-half dozen to several thousand trees. The Sequoias include the "big trees" and the redwoods. The diameters of some of them, three feet above ground, range from 12 to 23 feet, and in height the range is from 270 to nearly 400 feet.

Local Trees.—Although it is interesting to know about our giant trees, it is more important from a practical point of view that we take interest in and know about the trees that flourish in our own streets and parks. Not only are these pleasant to look at, but they actually aid in making us more comfortable in the hot season. By transpiration of water vapor from their leaves, they help to cool the atmosphere. They are constantly absorbing carbon dioxide and throwing off oxygen, thus helping to keep the air invigorating. Besides, they provide resting places and homes for our birds.

Every city is justly proud of its trees. However, they require care or they will not thrive. They must be protected from the attacks of insects, from fungous diseases, and from animals and other agencies that injure them.

Recognition of Trees.—Everyone should have sufficient knowledge to recognize, if not the species, at least the family to which our most common trees belong, and this knowledge is not difficult to acquire. In the first place it is helpful to know that only three families of our large trees have opposite leaves—the maple, the ash, and the horse-chestnut. Knowing this and a few characteristics of twig, bud, leaf, or fruit of different trees, it becomes quite easy to distinguish them.

The conifers, or cone-bearing trees, are readily recognized by their evergreen appearance and their cone-bearing habit. The sycamore is known by the mottled appearance of its bark, and the horse-chestnut by the horseshoe markings on the twigs. Trees such as the oak, ash, chestnut, catalpa, beech, locust, and walnut may be readily recognized in the autumn by their fruits. By practice one soon becomes acquainted with our common trees through their general appearance without stopping to think of individual characteristics.

Arbor Day.—Nearly every state in the Union has set aside a day on which the school children are especially encouraged to interest themselves in the planting of trees. It has become an annual custom for schools, especially in the rural districts, to observe a day of this kind by appropriate exercises followed by the planting of a tree. The object of Arbor Day celebration is to interest the coming generation in the importance of the conservation of tree life.

Precautions in Transplanting a Tree.—Everyone should know how to plant a tree in a proper manner so that it will live. In removing a tree for transplanting, great care should be taken not to break the root hairs. It is by means of these that the tree secures its food in solution from the soil. Removal necessarily causes the tree to lose its hold temporarily on the soil and thus reduces its power of absorbing water.

A wise gardener cuts off, or prunes, part of the top growth of a tree he transplants. By so doing he prevents too much evaporation of moisture from the leaves. Because their relation to the soil has been more or less disturbed, the root hairs are not able to supply water as fast as it is passed off by transpiration through the leaves if all are at work. The gardener by pruning reduces the number of leaves and so saves the tree. Even after a tree is properly planted, it is necessary to see that it has sufficient moisture and is protected from insect pests.

SUMMARY

A forest is a tract of woodland. The ground covered by the forest is called the forest floor.

Forests are important because they prevent floods, aid in maintaining a uniform flow of streams, retard the washing away of soil, assist in the formation of new soil, afford homes for wild animals and birds and yield various products useful to man.

The principal enemies of the forest are man, fire, insects and fungous diseases.

Forestry is a vocation whose object is the preservation and restoration of forests.

The United States began to take interest in the preservation of its forests in 1875. The work is in charge of a division of the Department of Agriculture, known as the Forest Service. The forests were not protected until this service was organized. There is still grave danger of the depletion of our forests.

Our forest preserves are located largely in the western and southern states, New England, Alaska, and Porto Rico.

Among the duties of the Forest Service are the prevention and control of forest fires, the protection of forest trees against disease and insect pests and the enforcement of sanitary regulations in all camps on the watersheds.

Trees, like other green plants, require food, air, light, water, and heat. Without these they cannot manufacture food or carry on their life processes.

Some trees attain great age and enormous size, notably the Sequoias of California.

In planting young trees, root hairs should not be broken, and top branches should be pruned to prevent too great transpiration. Care of trees after planting is essential.

Fact and Thought Questions

1. Name and describe briefly several trees you know.
2. What uses are made of trees in your neighborhood?
3. Explain how forests prevent floods.
4. Explain how forests aid in the formation of soil.
5. Describe methods of forest protection.
6. What effect does the close growing of trees in a forest have on their branches?
7. Suggest reasons for careful thinning out of natural forests.
8. Why is it necessary that the forests have protection?

9. What precautions should you take when camping to protect forest growth from fire?
10. Why do forest fires burn deep into the soil?
11. If a small fire started in woods near you, how would you fight it?
12. Why is smoking dangerous in forest areas?
13. Name five forest products.
14. State the purpose of Arbor Day in the schools.
15. State the object of forestry.
16. What enables trees to stand severe winds?

Projects

1. Make a collection of pieces of wood from trees valuable for commercial purposes. Label each piece.
2. Gather information on tree planting and prepare simple rules for transplanting and caring for evergreens and for deciduous trees, those which shed their leaves periodically.

Outdoor Observation

1. Make a field trip to observe the appearance of different kinds of trees and record your observations in your notebook. Note the natural tree growth of the region and also the trees set out for shade and ornamentation.
2. Observe the difference in growth of tree tops, trunks, etc., in crowded forest growth and in the open. Try to explain these differences. See how trees adapt themselves to difficult situations.

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CHAPTER XLII

PLANTS, HELPFUL AND HARMFUL

On every railway we see long freight trains made up of cars from every section of the country. In our great harbors we find steamers from every quarter of the world. Much of the freight of these carriers consists of plant products being brought to our doors from the points of growth or manufacture.

Once man depended for food, shelter and clothing on what grew about him. Today, if we trace to their source the foods, spices, medicines, clothing, and furnishings we use, we find the plant life of the entire world contributing to our health, comfort and pleasure.

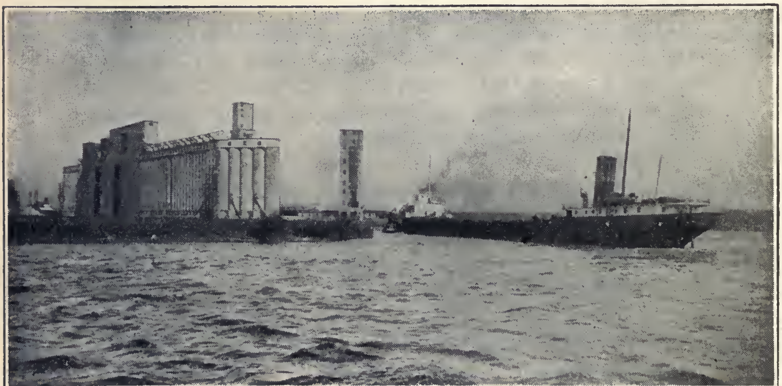
The plants that are most beneficial to mankind include those that produce materials for bread, building, beverages, ropes and twine, condiments, dyes, fabrics, medicines, oil, and sugar. Plants used for ornamental purposes might also be mentioned.

Food Plants.—The important food-producing plants are wheat, Indian corn, rice, millet, barley, rye, buckwheat, oats, cassava, arrowroot, the cocoanut, sago and date palms, sugar cane, the potato, the beet, and the sugar maple. Wheat, Indian corn, rye, oats, barley, and rice are commonly known as cereals, and are materials used for making bread and "breakfast foods." Of these plants wheat is considered the most valuable, since it contains, in the best proportion, the different food substances, especially the protein and starch, needed for the nutrition of the body. Of hardly less importance is rice, which contains a larger percentage of starch than the other cereals, and constitutes the chief food of more than one-third of the inhabitants of the world. In India, China, Japan, and the islands off the coast of Asia it is used most extensively.

Next to the cereals in starch-producing value stands the potato. Since its discovery over three hundred years ago it has steadily advanced in favor as an article of food, and is

now largely used in all the countries of Europe as well as in the United States and Canada.

Other important sources of starchy food are the arrowroot plants and the cassava. The roots of the arrowroot provide the chief food of the people in many tropical countries of the New World. Tapioca is manufactured from the roots of the cassava plant, a native of South America, and is largely used in this country. It forms an important article for export to the United States and Europe. Farina is also made from the roots of the cassava plant.



Brown Brothers.

GRAIN ELEVATORS AND GRAIN SHIP

Here, on the Great Lakes, grain is gathered and stored for distribution all over the world.

Sago, another pure starch food, is obtained from the pith of certain palm trees. It provides the people of Malaysia and southern Asia with a food material equal in importance to rice in other parts of Asia. In Europe and in our country it is used for making puddings and custards, and is considered to be an excellent food for infants and for invalids.

Sugar is obtained in great quantities from the stalks of sugar cane, a plant that belongs to the same family as corn, wheat, and the other cereals. Sugar also comes from beets, and from the sap of the sugar maple. The sugar made from beets is identical in

sweetening power to cane sugar, but its preparation is more difficult and more expensive. Maple sugar, when purified by the ordinary methods of refining sugar, is also very similar to cane sugar. However, when maple sugar is used without refining, it has a smoky taste quite pleasant to most people. Millions of pounds of maple sugar are annually produced in the United States and Canada.

SUGAR CANE
The greatest source of sugar.

Forage Plants. — Plants which animals eat either in a green or a dried state are known as forage plants. The principal plants included in this class are the different kinds of grass, some sedges, clovers, alfalfa, soy beans, and cow peas. The last four belong to a class known as the pulse family, and are especially valuable because of their ability to store the nitrogen of the air with the help of the bacteria that dwell on their roots. Since these plants use the nitrogen in building tissues that are to become the food of growing hogs and cattle, their importance is apparent.

Fiber-producing Plants.—The most important fiber-producing plants—those that yield material from which ropes, linen, muslin, cambric, and other fabrics are made—are hemp, flax, cotton, and jute. Rope and twine are made of the fibers of hemp and jute; linen from the fibers of flax; muslin and other cotton goods from the fibers covering the seed of the cotton plant. Burlap, carpets, and gunny cloth are also made from jute. A large proportion of the world's cotton supply comes from the southern states of our country. Flax is largely grown in the United States and in Europe, and especially in Russia. The best flax for linen

goods is grown in Flanders, Belgium, and in the north of Ireland. Hemp, useful for making twine, is produced from the fibers of plants that grow in Yucatan and in the Philippine Islands.

Fruit-producing Plants.—We depend on trees for healthful and delicious fruits. These are used raw or in preserved form. Owing to improvements in packing and shipping, fruit growing and fruit preserving have become great industries in this country. Our main commercial fruits are apples, oranges, grapefruit, peaches, pears, plums, and apricots. Bananas and figs are grown to a slight extent, but most of our supply comes from more tropical regions.

Brown Brothers.

ORANGE AND GRAPEFRUIT GROVE

Among the fruit-producing plants should be included such nut-bearing trees as the walnut, almond, chestnut, and pecan.

Beverage-producing Plants.—The most common plant products from which beverages are made are coffee, tea, cocoa, apples, grapes, hops, and several cereal grains. Coffee is made by boiling in water the ground berries of the coffee plant, which grows extensively in Brazil and, to some extent, in Java, the West Indies, and Mexico. Tea is made by steeping in water the leaves of the tea plant, which is widely cultivated in Japan, China, India, Ceylon and, to a less extent, in some other countries. Chocolate as a drink is made by adding milk or water to the roasted and ground seeds of the cacao tree, which thrives in several countries of South America, in the West Indies and in Mexico. Cocoa is made in the same way except that the fats have been removed from the ground seeds.

The fresh juices of many fruits are used to make delicious and healthful drinks. Orange juice has become especially popular for this purpose. Lemonade and limeade, made from the juices of lemons and limes, are excellent warm-weather bever-

ages. The juices of apples and grapes are also widely used. All these juices are obtained by crushing the ripe fruit.

Dye-producing Plants.—Among the dye-producing plants are the indigo, which grows only in tropical regions; the logwood, a tree that grows in the damp forests of Central America; the madder, a plant cultivated in India and Java, and to some extent in France, Holland, and central United States; and the annatto, a species of plant that thrives in the tropical countries of South America. Vegetable dyes obtained from these plants were formerly more widely used than at present. The discovery of coloring substances in coal tar, and their manufacture into products called aniline dyes, has to a large extent lessened the use of vegetable dyes. However, annatto holds its own as a harmless agent to give butter and cheese a rich yellow color.

Medicinal Plants.—Many plants produce substances used for healing purposes. Among the important ones are the cinchona tree, from the bark of which quinine is made; the camphor tree, from the wood of which camphor is distilled; and the castor oil plant, from the seeds of which castor oil is obtained. Ginger is made from the dried, pungent roots of the ginger plant, and rhubarb from the roots of the rhubarb plant. Peppermint is distilled from the stem and leaves of the peppermint plant. The native home of the cinchona tree is in South America; that of the camphor tree and the castor oil plant is in eastern or southern Asia, and that of the ginger plant is the West Indies. The other plants referred to flourish in various parts of the North Temperate zone. Other common plants often used for medicinal purposes are sage, catnip, comfrey, hoarhound, mandrake, tansy and flax.

Condiment-producing Plants.—The substances most commonly used as condiments, or seasonings, are cinnamon, clove, ginger, pepper, nutmeg, allspice, anise, mace, cassia, mustard, caraway, cardamon, coriander, caper and vanilla. These are obtained from the various parts of plants, the buds, seeds, fruits, bark and roots. Anise, cassia, pepper, allspice, cardamon, caraway, coriander, nutmeg, mace, and vanilla are obtained from the

seeds or the fruits of various tropical plants; cloves and capers from flower buds. Cinnamon comes from the bark of a tree, and ginger from a root. The leaves of parsley, fennel, spearmint, thyme and sage are also used as seasonings.

Oil-producing Plants.—The most important oil-producing plants are the olive tree, from the ripe fruit of which olive oil is extracted; the flax plant, which gives us linseed oil, largely used in paints and varnishes; and the castor oil plant, which gives us castor oil. Other plants from parts of which oil is obtained are corn, cotton, vanilla, wintergreen and various nut-bearing plants.

Brown Brothers.

AN ORNAMENTAL WHITE BIRCH

Tannin-producing Plants.—The barks of certain trees contain a substance called tannin needed in the manufacture of leather. The most important of these trees are the hemlock, spruce, larch, sumac and the different species of oak.

Wood-producing Plants.—Among the most valuable wood-producing trees are beech, black walnut, Douglas fir, mahogany, red cedar, rosewood, birch, maple, southern pine and oak.

Ornamental Plants.—Among the trees and shrubs most used for ornamental purposes are the American elm, Austrian pine, arbor vitæ, birch, Japan quince, lilac, roses of different varieties and spiræa. Barberry and privet are often used for hedges. A great variety of small flowering plants are used to beautify our lawns and gardens.

Non-Beneficial Plants.—Non-beneficial plants include poisonous plants and weeds. Among the plants listed by the United

States Department of Agriculture as poisonous are wild cherry, bittersweet, corn cockle, dwarf larkspur, great laurel, jimson weed, rattlebox, poison ivy, poison sumac, poison hemlock and snow-on-the-mountain.

Among the plants classed as weeds found in this country are burdock, Canada thistle, chickweed, dandelion, devil's paintbrush, milkweed, purslane, ragweed, smartweed, white daisy, wild carrot, yellow daisy and yellow dock. In New York State the cutting of weeds between fences and the highway is required by law in order to check their spreading and to prevent the aid they give to the making of snowdrifts in winter.

SUMMARY

Beneficial plants include all those that produce materials for food, shelter, clothing, medicine and ornament.

The food-producing plants include all cereals as well as other starch and sugar-yielding plants such as arrowroot and sugar cane and many fruit trees.

The wood-producing plants include all large trees from which lumber may be manufactured.

The plants that yield material for clothing are those that have fibrous tissue, such as cotton and flax.

There are many plants from which medicine is obtained, such as the cinchona and camphor trees and various herbs.

Among ornamental plants are the Austrian pine, the American elm and numerous shrubs and small flowering plants.

Non-beneficial plants include certain poisonous plants and weeds.

Fact and Thought Questions

1. Mention ten plants that provide man with starch and protein.
2. Name several forage plants.
3. Name several fiber-producing plants and state the special use of each.
4. Name several beverage-producing plants.
5. Name several dye-producing plants.
6. Name several medicinal plants.
7. Name several oil-producing plants.
8. Tell how we draw on distant parts of the earth for plant material used in our daily life.

9. Why protect wild flowers?
10. Name shrubs used for ornamental purposes.
11. Name ten plants classed as weeds.
12. In what ways do weeds injure our gardens and lawns?
13. What is one of the worst weed pests in your locality?
14. Why is it wise to clean up and burn weeds in the spring and fall?
15. Name and describe any poisonous plant in your neighborhood.

Projects

1. Make a collection of various kinds of fiber used for commercial purposes. Label each kind.
2. Make a collection in small bottles of various drugs that are obtained from plants. Label each bottle.

Outdoor Observation

1. Make a field trip to observe and to collect specimens of weeds common to your general neighborhood. Note distribution and conditions of growth.
2. Make a field trip to observe and list plants beneficial to mankind, growing wild or cultivated in your general neighborhood.

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CHAPTER XLIII

OUR BALANCED WORLD

This old world of ours is like a giant scale which is continually being kept in balance. Or it is like a column of constantly changing figures that always add to the same total.

We have seen how energy is continually changing its form, yet no energy is ever lost. We have seen how matter is separated into its elements and these are recombined into other substances, yet in all these changes no matter actually ceases to exist.

There is an astonishing balance between the various forms of life on earth in which every animal and plant has a part. Man is learning more and more to control this balance, fighting harmful plants and animals and protecting useful ones. The study of our balanced world and of man's relation to it is a fascinating one, which casts a new light on the laws of science we have come to know.

A Balanced Aquarium.—An aquarium is a water-filled tank or globe in which water animals and plants are kept. A balanced aquarium is one in which the materials needed for the continued life of both animals and plants are mutually provided. This means that the animals provide material which the plants are able to make into food for their own nourishment and the plants in turn provide nourishment for the animals. An aquarium containing green water plants, such as water hyacinths and Elodea, and fish, snails, and water bugs is said to be balanced when each organism thrives.

In a balanced aquarium the plants serve as food for the animals. They also throw off oxygen which is used by the animals. In return for this the animals excrete carbon dioxide and nitrogenous matter, both of which are used by the plants as raw material for the production of new food. Thus all the necessities for continued life are provided by the organisms within the

aquarium and life will go on even if the aquarium is sealed tight. We have learned that in the sunlight green plants absorb carbon dioxide and combine it chemically with water in the making of carbohydrate food. During the process oxygen is given off. In the aquarium, the fish and other animals use this oxygen in respiration, and throw off carbon dioxide resulting from the chemical combination of the oxygen with the food elements in their bodies,

Brown Brothers.

A Balanced Aquarium

The materials needed for the continued life of both animals and plants are mutually provided.

thus providing the carbon dioxide needed by the water plants in making food. This process is often referred to as the *carbon-oxygen cycle.*

In the aquarium the fish and other animals change a portion of the plant food they eat into the protein substance of their bodies. When this substance is decomposed and excreted in the

form of nitrogenous waste it is once more taken up by the plants and made into protein plant tissue that animals again eat. This process is sometimes called the *nitrogen cycle.*

A Balanced Terrarium.—A balanced terrarium is a box containing earth in which land animals and land plants supply each other with the materials needed for continued life. The animals provide substances which the plants are able to use as raw material in making food, and the plants, in turn, provide food and oxygen for the animals. In a balanced terrarium containing insects and earthworms and growing plants, the animals feed on plant tissue and breathe air containing oxygen given off by the plants. The plants use the carbon dioxide and nitrogenous matter excreted by the animals, together with the nitrogenous matter resulting from the death of organisms in the terrarium, as raw material for the manufacture of food, the same as in a balanced aquarium. Life will continue in a balanced terrarium even if it is sealed air-tight.

A Balanced World.—In the balanced aquarium and the balanced terrarium life is maintained because the plants and the animals mutually supply each other with the necessities of life. Our world is really a giant balanced aquarium and terrarium combined. The green plants make and store food. Animals and certain non-green plants that cannot make their own food live on this stored food. In the bodies of these animals and plants the food is broken up into new compounds a part of which is returned to the soil to be recombined into food by the green plants. These processes are continuous.

Starch and sugar, the carbohydrate foods, are broken up in the bodies of man and animals into carbon dioxide and water. The carbon dioxide is returned to the air, and the water to the soil. Both are taken up again and remade into food by the green plants. Protein foods are broken up into compounds containing nitrogen. These are returned to the soil, and are taken up by plants to make more protein food.

These processes have been going on for ages and will continue as long as climatic conditions permit. They are never-ending cycles and insure the retention of a balanced world.

It is interesting, in considering our balanced world, to note how the various types of living things are fitted to take their part in the carbon-oxygen cycle. Animals with lungs, such as the frog or the dog, breathe in oxygen and exhale carbon dioxide. Insects take in oxygen through tiny holes, or *spiracles,* in the sides of their bodies, and through them give off carbon dioxide. Fishes and other water animals take oxygen from the water by means of feather-like organs called gills, and through them give out carbon dioxide. Trees take in oxygen through minute pores located in their growing, or cambium, layers, and also excrete carbon dioxide through these pores. In all living things, oxygen is taken in and used in oxidation, and carbon dioxide is given off.

In the interrelation of plants and animals the dependence of all animals on plant life for food is clearly evident. At first one might think that some animals live almost wholly on animal food and therefore are not dependent on plants, but a little reflection shows that they really are dependent on plants, since the animals on which they feed derive their nourishment from plants.

Many animals depend on plants not only for food, but for shelter and protection as well. Nearly all wild animals seek the forest or the jungle as a refuge from their enemies, and many make their homes there. Birds build their nests in the branches of trees or, like the woodpecker, in holes in the trees. Bees often make their homes in hollow trees. So do squirrels. Many kinds of insects live on trees, shrubbery and grass.

Relation of Animals to Man.—Most of the animals of the world are regarded either as the friends or as the enemies of man. Many, like the domesticated animals of home and farm, are very useful. Others do harm, causing disease, death or loss of property.

Domestic Animals.—Early in his history man tamed certain animals and made them serve him. They were important factors in his rise to civilization, and they are still very important. Without horses, cows, sheep, hogs and fowls, farming would be greatly restricted and the food supply of the world would be dangerously reduced.

Birds.—Birds in their relation to man are both beneficial and harmful. They are beneficial when they destroy insects, rats and

mice, and weed seeds, or when they act as scavengers. They are harmful when they eat grain, fruit, and fowl.

The Division of Biological Survey connected with the Department of Agriculture reports that a large number of birds, formerly considered undesirable because they were supposed to destroy much grain, are on the whole useful, since they kill vast numbers of insects that feed on vegetation. These include swallows and starlings. Even the crow has something said in its favor.

Among birds that are useful as killers of rodents are owls and hawks of various kinds. Cooper's hawk, the sharp-shinned hawk, and the great horned owl are considered harmful, since they are enemies of birds and poultry. As all birds must have food to survive, they should be judged by the net result of their work. Any bird that is more useful than harmful should be protected.

Rats.—Of all the mammals in the world, rats are the most harmful to man. Because they live in drains, sewers, and other filthy places they are often the carriers of the germs of infectious diseases. Rats also harbor on their bodies fleas that are sometimes carriers of the germs of the dread bubonic plague. For this reason special steps are taken in our ports to prevent the escape of rats from ship to shore.

Rats are also great destroyers of property. It is estimated that rats in this country alone destroy over $200,000,000 worth of grain in a single year, besides doing enormous damage to property of other kinds.

Fishes and Other Sea Creatures.—Fishes are a great source of food for man. Every year millions of pounds of salmon are taken from rivers flowing into the northern Pacific, and vast quantities of cod, haddock, mackerel and other food fishes from the waters of the Atlantic. In addition, a vast business is carried on in the catching and selling of edible fresh water fish. Modern refrigeration methods enable us to ship large quantities of fresh fish to all parts of the country. The balance of the catch is preserved for future use by canning, salting, and drying. Aside from the fishing industry, there is sport fishing which supplies recreation for millions of people.

Everyone is familiar with the common bath sponge. Sponges grow on the sea bottom in various warm sections of the world, especially in the Mediterranean and the Red Sea and in the ocean around the West Indies and Florida. They are gathered in great quantities, dried, and prepared for the market. The annual value of the sponge crop amounts to several million dollars.

Corals are small but very numerous animals living in clear sea water of moderate depth. Since they live in enormous colonies their limy skeletons in time form great reefs. Many islands in the Pacific ocean and parts of some continents originated from coral reefs. Coral rock is often beautiful in color and is made into ornaments of various kinds.

Mollusks, especially oysters, clams, mussels, and scallops, have always been a source of food for man. Their shells are used as material for making buttons, knife handles, and ornaments of various kinds. Even the cuttle-fish furnishes cuttle bone, a limy substance used to make polishing powder. Cuttlebone is often placed in bird cages to supply birds with needed lime and salt. Cuttlefish also supply sepia, a rich brown liquid used by artists for coloring.

Bees Collecting Nectar and Pollinating Flowers

Insects.—When plants are in flower they are constantly visited by bees and other insects. These insects are not there for pleasure. They are seeking material for food. Bees secure the nectar of flowers and manufacture it into honey which they store for future food. Man, taking advantage of their industry, secures the results of their work for his own profit. While getting this food material, insects unconsciously render a great service to plants and also to man, for they carry on their bodies, from flower to flower, the precious powder called *pollen* without which plants cannot develop fertile seeds. Bees,

butterflies, moths, and certain flies are the chief pollen-carriers of the world.

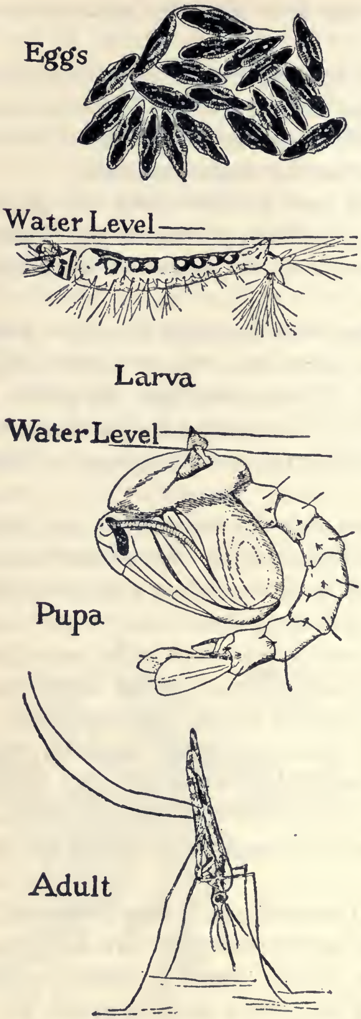
In California the growers of figs imported a certain insect in large numbers and placed it among the fig trees in order to insure pollination, or the transfer of pollen from flower to flower. Before its introduction the fig industry had not been profitable.

Some insects are harmful to man because they are greedy eaters, destroying plant life by feeding on leaves and stems; others because they are instrumental in the spread of many dangerous diseases.

How Insects Carry Disease.—Insects spread disease in three ways: (1) they may bring the germs on the surface of their bodies to a wound, to food, or to drink; (2) they may bear the germs of infection in their digestive tracts; (3) they may harbor the germs during development and transmit them to human beings by biting them.

Disease germs are carried not only by mosquitoes and flies, but by roaches, fleas, lice, and bedbugs as well. Experiments have been made in which these insects were caused to walk over cultures of various disease germs, and many hours later were made to walk over sterile agar plates, having been kept in the meantime under conditions as natural as possible. Examination of the agar plates afterward showed active cultures of the different kinds of infectious germs. Insects carry germs on their feet, on their wings and on their bodies. It seems that, when this fact is well understood, everyone will make every effort to destroy all disease-carrying insects. Cleanliness and the use of insecticides are the best protection against them.

Mosquitoes.—The relation of mosquitoes to man is especially harmful. They are not merely an annoyance—they are dangerous pests. They harbor a parasite, which causes a disease called malaria. In order to understand how these malaria germs get a foothold in the human body, it will be necessary to consider their life history. Their natural home seems to be in the body of a certain kind of mosquito known to scientists as the *anopheles.* They develop in the mosquito's digestive system and make their way into its salivary glands. If the mosquito bites a person after the parasites



U. S. Dept. of Agriculture.

THE METAMORPHOSIS OF A MALARIA MOSQUITO

have lived in these glands a few days these parasites may pass along with the saliva into the blood of the person bitten. Here they soon establish themselves in the red blood corpuscles where they grow larger and develop spores. The growth of these spores causes serious injury to the corpuscles, breaking them down and releasing the spores into the blood current together with a poisonous substance which has been generated. This poisonous substance affects the human system so seriously that chills and fever follow. Physicians prescribe quinine in large doses to cure malaria. No other effective remedy has been discovered.

The only sure way to eliminate malaria in sections where it exists is to exterminate the mosquitoes. This may be done by draining pools of stagnant water or by pouring oil on their surfaces. Mosquitoes lay their eggs on water, and these soon hatch into active larvae, or "wigglers", which shortly develop into less active pupae. Though both larvae and pupae live in the water, they breathe air, and the presence of oil on the surface of the water shuts off their air supply and soon kills them.

Another species of mosquito, the stegomyia, carries yellow fever much as the anopheles carries malaria. For many years yellow fever was a dread disease throughout the tropics. It made Cuba a dangerous and unhealthy place, and was so prevalent in Panama that early attempts to build a canal across the isthmus had to be abandoned because of the many deaths among the workers from this disease.

That yellow fever is spread by a certain kind of mosquito was proved experimentally in Cuba by Drs. Walter Reed, James Carroll, and Jesse Lazear early in the present century. In the course of the experiments Dr. Lazear took the disease and died, a martyr to science. At once the work of wiping out these mosquitoes was started, and Cuba no longer suffers from yellow fever.

Profiting by this discovery, Col. Wm. C. Gorgas, Chief Sanitary Officer of the Panama Canal, performed one of the greatest works of sanitation in history, cleaning up the region so thoroughly that yellow fever and other tropical diseases were practically wiped out.

The Common House Fly.—Besides being a nuisance, the common house fly is a positive menace to health. It is an enemy to mankind. It is born in filth and delights to live in unclean places from which it brings germs of disease into our homes and deposits them on the food we eat.

Consider the life history of the fly. The female usually lays eggs in manure piles or on refuse where there is decaying organic matter. Under favorable conditions of temperature the eggs soon hatch into worm-like creatures called maggots. These maggots are greedy eaters. They secure food from the refuse and grow rapidly for a few days; then they apparently cease their life activities and have a resting period. This is called the pupal stage. A few days more and they develop into adult flies.

As flies breed very rapidly they soon become exceedingly numerous in warm weather wherever filthy conditions exist. If they stayed where they were born they would not be so dangerous. But they do not. In search of warmth or food they make their way into our homes, or else seek the market places where meat and fruit are exposed. Over the food they walk

and leave particles of filth that are often laden with germs of disease.

Flies possess some remarkable structural adaptations which make them very alert. They have large compound eyes that move freely from side to side, making them keen observers. Thanks to their membranous wings they are rapid movers. Their mouth parts are so made that they form a proboscis, or feeding tube, well adapted for both lapping and sucking food. Their feet have pads on which tube-like hairs develop that secrete a sticky fluid. Thus they are able to walk as readily on the ceilings and walls of our homes as on the table. This fact enables them to leave germs of disease not only on our food, but in all parts of our rooms. It is possible for them to bring into our homes not only typhoid germs but also germs of tuberculosis and other dangerous diseases. Hence the need of getting rid of them.

How to Get Rid of House Flies.—There are several ways of getting rid of house flies, such as by dishes of poisonous liquid, sticky paper, and traps. Screens will keep them out of the house and away from food. By far the best method of control yet found, however, is the removal or destruction of their breeding places. It seems hopeless wholly to exterminate them, but their multiplication can be controlled. Every one should encourage the destruction of the places where they grow and develop. Manure heaps and all garbage and excretions of every kind should be removed from the vicinity of homes. Such action will do much to get rid of the fly nuisance.

SUMMARY

The interrelation of plants and animals in the world may be understood by the study of life in a balanced aquarium or terrarium.

Green plants are the makers of food and so render service both to other plants and to animals. Animals and non-green plants break up food into elements and compounds that are again used by green plants.

In their relation to plants and to man some insects are beneficial and some harmful. The same is true of birds.

Some forms of animal life, notably mosquitoes, flies, and rats, are especially harmful to man because they are carriers of disease germs. Every possible effort should be made to do away with these pests.

Fact and Thought Questions

1. Explain how a balanced aquarium illustrates the mutual aid of animals and plants.
2. Describe the carbon-oxygen cycle.
3. Describe the nitrogen cycle.
4. What may happen in a locality if there is not enough plant life for the animal life?
5. How do bees and flowers afford mutual aid?
6. Discuss the beneficial relations of birds to man.
7. What might happen if all birds were driven away?
8. Is it always advisable to drive away birds that eat some of our berries or fruit?
9. Discuss the relation of the rat to man.
10. Discuss the relation of the mosquito to the health of man.
11. Discuss the relation of the house fly to the health of man.
12. How does a thorough clean-up of the home yard aid our fight against animal carriers of disease?

Projects

1. Make a balanced aquarium.
2. Make a balanced terrarium.

Outdoor Observation

1. Observe and list forms of animal life in your general neighborhood that are injurious to man.
2. Observe the birds in your neighborhood, noting so far as possible what they eat. Record your findings.
3. Observe and report on conditions in your neighborhood which favor the breeding of flies and mosquitoes. Suggest remedies.

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CHAPTER XLIV

SCIENCE AND PROGRESS

Step by step, in one field and another, we have been increasing our knowledge of common things. We have come to see how Science has given us both understanding and control of the great forces of Nature, how it has increased our physical comfort and our happiness, and how, by giving us an understanding of our bodily machinery, Science has lengthened life itself. Today, as never before, we are in real working accord with our environment.

It remains for us to take a bird's-eye view of the whole field we have been studying, that we may see how the part Science has played in human progress justifies calling the present age "The Age of Science."

The gradual betterment of our living conditions and general welfare, the steady improvements in our methods of protecting and restoring health, the improvement in means of communication and transportation and in preserving and making available to all the scientific knowledge already gained illustrate what we mean by progress, or advance in civilization.

In early times, and until the last two centuries, progress was slow and uncertain, and often did not materially help mankind as a whole. Progress became rapid and widespread in its effects only as man learned the great laws of nature by careful experimenting and by making use of observed facts. By so doing, he has come to control and use the forces of nature.

Having classified into sciences his knowledge of the various fields of his surroundings, man finds it increasingly easy to apply this knowledge in endless ways. With the help of Science, discoveries and new applications of the powers of nature are being constantly made which will still further add to our comfort, welfare, and progress.

Science and Transportation.—Early man had to walk when he wished to travel, and was able to take with him only what he

could carry. Later, having domesticated the horse, he learned to ride. By degrees he developed drags to carry his goods, then solid-wheeled carts, and, after centuries, the four-wheeled wagon with spokes and tires. The stage coach lines were his first regular transportation system.

A marked step forward in transportation was taken when Stevenson, early in the 19th century, adapted the stationary steam engine to transportation and produced a practical locomotive to draw cars on rails. Gradually railroads linked communities together. Locomotives grew in power and better cars and tracks kept pace with their development. Today Science has made possible engines that draw more than a hundred loaded freight cars, and high speed engines which draw passenger trains equipped with all conveniences for day and night travel. Now Science is going a step farther by using electric locomotives which haul trains across plains and over mountain ranges, utilizing the power of distant waterfalls.

Science triumphed again when, in the closing years of the 19th century, the gas engine made possible the development of the automobile. Science has steadily improved the automobile until its use has become practically universal in this country, both for business and pleasure. Local and long distance automobile truck and bus lines for freight and passengers are rapidly increasing in number.

The invention of the gas engine made possible the airplane, man's most rapid means of transportation. In the quarter century since the Wright Brothers developed the first practical flying machine, Science has steadily improved the airplane until we have machines capable of sustained flights of thousands of miles at an average speed of more than 100 miles per hour. During this same period the dirigible balloon has been developed into a practical machine. The airplane and dirigible are bringing about new wonders in transportation.

Modern Science has also brought about marked progress in water transportation. From the straddled log and primitive dugout, man slowly evolved the galley of early Egypt, Greece, and

Rome, propelled largely by oars. Later, sails were added and in time ships were driven entirely by wind.

When Fulton, in 1807, adapted the steam engine to driving a boat regardless of wind and tide, a new era in water transportation began. By degrees ships grew in size and strength, paddle-wheels gave way to propellers, and steam turbines took the place of old-time engines. The enormous steamship of today, more than ten times as large as Columbus' largest vessel and many times greater in carrying capacity, is a striking product of centuries of progress in many sciences.

Not only did Science make possible the great ships of today, but it also gave the means to keep them accurately on their courses. For centuries the sun and stars had been the mariners' only guides. Then Science gave them the compass to tell direction and the astrolabe to determine latitude. With these instruments Science guided Columbus to America. Today the compass has been made far more reliable, the sextant gives latitude accurately, the chronometer helps determine longtitude, and the log indicates speed. Buoys and lighthouses warn ships from shoals and reefs and guide them into harbors. Radio keeps ships in contact with land and with other ships. So Science has made travel by sea far more rapid, far more comfortable, and far safer than ever before.

Science and Communication.—Messages of early times were transmitted by word of mouth. With the invention of writing, communication was extended, messages being sent by runners or horsemen. Later, as modern civilization developed and correspondence became common, mail routes were established, letters being carried by post riders and stage coaches. These in turn gave way to railway mail transportation until today we have mail trains equipped to take on and deliver mail without stopping and to sort and sack mail enroute. Science, too, is making possible even more rapid transmission of written messages by the use of the airplane. Air mail service is already well established and is being rapidly extended. It carries our letters much faster than do the fastest trains.

Previous to 1844 the message sent by train represented the most rapid form of communication. In that year, however,

Samuel F. B. Morse gave to the world the telegraph, which marked the greatest single stride in the advancement of communication. It shortened the time required for a message to pass between far distant points from days or hours to minutes or seconds, and opened a new era in business. In 1858, Cyrus W. Field, by laying the first Atlantic cable, extended the principle of the telegraph to communication with foreign lands. This in turn promoted international business, and facilitated the gathering of news.

The invention of the telephone in 1876 by Alexander Graham Bell led to a new means of communication, simple in its operation, and easily installed in any home or office. Probably nothing has done more to tie communities together and to increase business than the telephone. We need only notice the extent of its use in our own neighborhood to realize its tremendous importance in our modern life.

Late in the 19th century, Marconi gave to the world wireless communication, or radio. Here again was a distinct advance, for messages could be sent by waves in the ether in any direction, without wires. At first, wireless messages were sent by telegraph code. Scientists, today, however, have so perfected radio transmission and reception that music, the human voice, and even pictures may be sent great distances and reproduced accurately wherever there are proper instruments for their reception.

Modern radio is a splendid example of what Science can do. Already it enables ships to keep in constant communication with the shore and with each other, summoning help when disaster threatens, or receiving warnings of approaching storms, icebergs and other perils. Through the broadcasting of concerts, lectures, news bulletins, and athletic contests, it furnishes entertainment and instruction for many millions of people. Through weather forecasts it serves the growers and shippers of fruit. Yet radio is seemingly still in early stages of development and Science will undoubtedly make it even more wonderful and useful to us as time goes on.

Science and Building.—Wonderful structures were built in past ages. Their construction, however, was very slow with

tremendous cost in human life and labor. Most of the people in those days were poorly housed, with living conditions far from sanitary. Today modern science has revolutionized building, making it possible to erect with astounding speed safe, attractive, sanitary buildings well adapted to our various needs.

Science has developed improved methods of quarrying, cutting, and polishing building stone, of making brick, and of shaping lumber. Science has given us concrete and steel to build with—two materials largely responsible for our tall buildings, great factories, bridges, dams, and roadways.

By means of labor-saving devices, such as the steam shovel, the power derrick, and the automatic riveter, Science has enormously reduced hand labor and speeded up construction.

By the development of proper heating, ventilating, and plumbing systems, Science has safeguarded health and assured not only comfortable working conditions in our offices and work shops, but also increasingly comfortable homes.

Science and Industry.—From the dawn of civilization until a century ago, industry progressed very slowly. In the early days, the members of each family made by hand their crude tools, their shelter, their clothes, and their furniture. With the growth of town and city came specialists, such as the carpenter, the tailor, and the shoemaker, but poor tools limited their output and they usually served only their own community.

When Science gave to man the stationary steam engine and the railroad, manufacturing progress became rapid. Machines were invented which quickly and efficiently do the work formerly done laboriously by hand. One man can now do the work of the many in former days. Moreover, railways now bring raw materials from a distance and carry away manufactured goods, thereby speeding up industry and extending the markets.

The discoveries in electricity and the invention of dynamos and electric motors have still further helped industry, for the power of distant waterfalls, formerly going to waste, is now transformed into electricity, transmitted hundreds of miles by wire, and used in motors to drive machinery with greater economy than by the use of steam.

Science and Farming.—Science has revolutionized farming. It has gradually replaced the crude ox and horse-drawn implements with marvelous power-driven plows, harvesters, and other machines. One worker on the farm may now accomplish what formerly required many men.

Science has given the farmer knowledge of the soil and of fertilizers to enrich it, thus insuring more bountiful crops. It has made him familiar with common diseases and parasites that attack his crops and animals and has taught him how to combat them. Through Science new varieties of plants and finer breeds of animals have been produced, which yield higher grades of food and other essential products.

Science has shown the farmer that dry areas, once considered worthless, may produce crops by dry-farming and that other desert areas may be made exceedingly fruitful by irrigation with water stored behind great dams.

Once the farmer grew crops only for his own use or to sell in his neighborhood. Now good roads and automobile trucks enable him to reach the railways. Scientific methods of packing and refrigerating make possible the safe shipment of perishable crops long distances by rail or ship. The farmer, who once served only his own locality, now serves the whole world.

Science and Health.—Perhaps the greatest service Science has rendered us is in the field of health. By scientific methods in the cure and prevention of disease, the average length of life is being steadily increased.

In early days it was believed that diseased people were possessed of evil spirits, and strange and useless ceremonies were performed to drive the spirits out. Little or nothing, however, was done for the patients themselves, and they often died. Then, gradually, it was realized that sickness was the result of something wrong with the body. Scientific study began to discover the functions of the body and to determine the right medical treatment for illnesses.

Following the invention of the microscope early in the 17th century, scientists quickly discovered the relation of microorganisms to infectious diseases. Pasteur and others, studying these

minute forms of life, learned how to combat them in the body, to rid food and water of them, and to preserve food from their attacks by drying, canning, refrigeration and other means. Lister developed the antiseptic method in surgery, which prevented germ infection after an operation. From this has developed our modern aseptic surgery which excludes germs before and during the operation. Jenner discovered that germs of cowpox, injected into the body, made one immune to smallpox. This led to the discovery of vaccines and antitoxins which prevent the spread of several dangerous diseases.

By the scientific study of the necessary food nutrients present in common foods, it has become possible for scientists to recommend diets that keep the body in the best condition to resist disease and to perform its work.

Other scientific discoveries also have contributed to our better physical welfare. The X-ray discloses the character of injuries to the bones and locates foreign objects and abnormal growths in the body. The development of safe anaesthetics reduces suffering during operations and the accompanying dangers of shock and fright. Even the scientific advances in building have contributed by giving us more comfortable and sanitary homes. On every hand, Science is working to safeguard our lives.

Science and Our Daily Life.—We are so accustomed to the many comforts, pleasures, and conveniences of our daily lives that we find it hard to realize the extent to which we are indebted to scientists for them.

The comfortable houses we live in are the product of scientifically developed tools, building materials, and working methods. Long scientific research in metals and manufacturing processes lies back of our efficient modern and sanitary plumbing with its attractive fixtures. Modern scientific methods of water supply bring pure water from a distance to meet the needs of the home. Modern heating plants, designed on scientific principles, keep us comfortably warm regardless of winter's storms.

Since the days of Franklin, scientists have striven to make electricity useful in the home. Steadily its uses have increased. Electricity now lights our homes and runs our radios, washing

machines, sewing machines, refrigerators, coffee percolators, and many other appliances. Electricity makes our streets safer at night, carries us to and from our work, and helps run our automobiles. Almost daily, scientists find new ways in which to make it serve us.

What Science has taught us about food nutrients and food values has insured a better selection of food for our table. What it has taught about bacteria has enabled us to safeguard our food supplies and to protect them against spoiling. What Science has taught us about infection enables us more and more to protect ourselves against disease.

Many of our amusements are the gifts of Science. The radio, the moving picture, the phonograph, the piano, and the automobile we owe to scientists who labored hard to learn the secrets of electricity, light, sound and other forms of energy, and to make them contribute to our needs and pleasures. Steadily Science is giving us new and deeper insight into the wonders of the materials and forces in our surroundings, enabling us to use them more and more for our happiness and good.

SUMMARY

Progress means the continued betterment of our living conditions and general welfare. Modern Science has made progress rapid.

In transportation, Science has largely replaced the horse and wagon with the modern train, the automobile and the airplane; in place of the sailing vessel it has given us great steamships.

In communication, Science has supplanted the messenger on horseback with modern mail service by rail and airplane and with the telegraph, the telephone and the radio.

To buildings and other structures, Science has contributed new materials, such as steel, and new methods and powerful machines to reduce hand labor. Construction is now a rapid process.

Science has taught the farmer how to produce more fruitful crops and better animals, how to combat his natural enemies, and how to make dry land produce crops.

Progress in industry has been rapid since the invention of the steam engine and the turbine, and the development of electric power. Modern machinery is increasingly automatic, reducing hand labor and cost of production. Progress in transportation has also markedly aided industry.

Science has rendered exceptional service in the protection of health and life by introducing better treatment of diseases, by improving sanitary conditions, and by showing us how to select, prepare, and preserve our foods.

Science affects our daily lives in countless ways. It is responsible for comfortable and sanitary homes, and for their conveniences. It provides many of our amusements. It protects our lives in endless ways.

Fact and Thought Questions

1. Why has the human race experienced more improvements in living conditions during the last 200 years than before that time?
2. Trace the development of transportation.
3. Outline the progress made in communication during the last century.
4. Show how each of several branches of science contributes to the making of a modern office building.
5. Name several applications of Science to some special industry.
6. How has Science improved farming?
7. How does Science protect health?
8. Name ten articles in your home that are products of Science.
9. Name some field in which distinct scientific progress has been made in your lifetime.

Projects

1. Make a detailed study of some one field of scientific progress, such as land transportation. Outline steps in that progress. Illustrate your statement with drawings. Make a model of one form of transportation.

Outdoor Observation

On your way to and from school observe and list objects that illustrate modern scientific progress in each of at least three fields.

CHAPTER XLV

FAMOUS SCIENTISTS

A scientist discovers and perfects a serum for protection against a certain disease. In the years that follow, its use saves thousands on thousands of lives.

An inventor designs an odd-shaped glass bulb containing thread-like wires, and electricity banishes darkness. Another works long days with wire, magnet and metal disc. Suddenly we are able to talk with people far distant from us. Others invent, and voices come to us from afar through the air. What scientists discover serve the world.

These scientific men and women, some unknown or little known, have not spared themselves. They have labored long and hard. Some have sacrificed fortunes and friends; others have given health and even life itself, that truths might be discovered for the benefit of all. The roll of scientists and inventors is a great honor roll.

We have learned that much of the progress of the world has been possible through the application of science. Back of this progress is a whole procession of men and women, some of whom gave their lives to learn more of the great truths that underlie all scientific achievement. The story of their training and life struggles, of their methods of work, and of their devotion to science is a fascinating one. Even the brief glimpse given here into the lives of a few of them should inspire all of us to accomplish things worthwhile.

Among the men and women who have done much to advance science we find Francis Bacon, Galileo, William Harvey, Sir Isaac Newton, James Watt, Michael Faraday, Joseph Henry, James Prescott Joule, Louis Pasteur, Edward Jenner, Charles Darwin, Joseph Lister, Alexander Graham Bell, Luther Burbank, Thomas A. Edison, Madame Curie, Wilbur and Orville Wright, Albert A. Michelson, Robert A. Millikan, Albert Einstein, Irving Langmuir, and Arthur H. Compton.

Bacon.—Francis Bacon (Lord Bacon) was born in London, England, in 1561. His father was Lord-keeper of the great seal in the reign of Queen Elizabeth, and his mother is said to have been a woman of fine talents. At the age of twelve he went to Cambridge, where he was considered very studious, and gave promise of a distinguished career. After leaving Cambridge he continued his studies in France.

On his return to England, Bacon studied law and was admitted to the bar in 1582. At the age of twenty-three he was chosen a member of Parliament and soon became one of the queen's advisers. When James I. became king, Bacon was especially favored at court and in 1613 became attorney-general. He was knighted and in 1618 became Lord High Chancellor of England, a most important office.

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FRANCIS BACON
Originator of the Experimental Method.

Bacon's greatest service, however, was not in the line of politics. He was the originator of the modern method of scientific study. Observing that students accepted conclusions of others with little or no reasoning of their own, he became convinced that a method based on the careful examination of things was the proper way of acquiring accurate knowledge. Accordingly in later years he produced a remarkable treatise known as the Novum Organum in which his new method of study is set forth. It advocates the discovery of truth by observations and experiments rather than by the acceptance of statements on the authority of others. He died in 1626.

Galileo.—Galileo was born in Pisa, Italy, in 1564. He was the son of a musician. In his youth he studied music and painting as well as mathematics and the classics. He was especially

fond of mathematics and at an early age became distinguished for his knowledge of this subject. In later years he used this knowledge in carrying on his scientific experiments. He invented the thermometer, and discovered the laws of the pendulum and of falling bodies. He introduced into Italy the experimental method of study which was being advocated by Bacon in England.

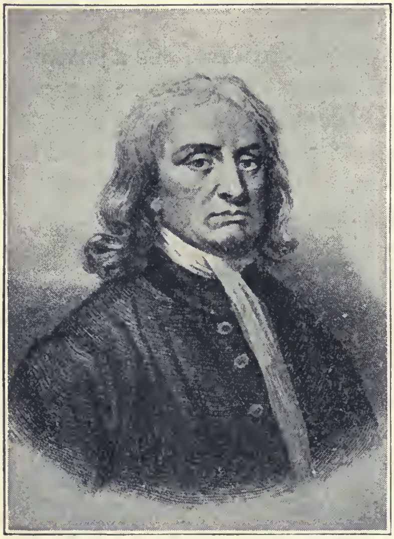
Galileo was distinguished both as an astronomer and a physicist. By the use of the telescope he was the first to discover the mountainous character of the moon, the phases of the planet Venus, the satellites of Jupiter, and the rings of Saturn. He advocated the Copernican theory of the universe, which represents the sun as the center with the earth and planets moving around it. For this he was greatly persecuted. He died in 1642 at the age of 78.

Harvey.—William Harvey was born at Folkstone, England, in 1578. He was graduated from Caius College, Cambridge, at the age of nineteen and went to the University of Padua, in northern Italy, at that time the most celebrated school of medicine in the world. Later he became the court physician of Charles the First of England. Harvey is known as the man first to demonstrate the circulation of the blood in the body, and as the father of embryology. The latter title was given him because he watched the hatching of hens' eggs, one of which was opened daily to see the progress and the manner of growth of the chick. He died in 1657.

Newton.—Sir Isaac Newton was born in Lincolnshire, England, in 1642, the same year in which Galileo died. He was the son of a farmer, who endeavored to educate the boy to follow the same vocation. But the lad neglected his farm duties to make mechanical toys. A sun dial made by him is still in existence. His mother, recognizing his ability, sent him to school. At the age of eighteen he became a student in Trinity College, Cambridge, and took his first degree at the age of twenty-five. He was especially proficient in mathematics and at the age of twenty-seven became professor of mathematics in his college.

Although he wrote many articles on mathematics and physics, he is best known for his discovery of the theory of universal

gravitation. You recall how his observation of an apple falling to the earth from a tree caused him to connect the force that attracts all objects toward the center of the earth with the force which keeps the planets in their orbits. This was set forth in his treatise known as the Principia.



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SIR ISAAC NEWTON
The Discoverer of the Law of Gravitation.

Newton formulated three statements now accepted by scientists as the laws of motion: First, every body continues in a state of rest or of uniform motion in a straight line unless impelled by external force to change that state; second, the rate of change of momentum is proportional to the force acting, and takes place in the direction in which the force acts; and third, to every action there is an equal and opposite reaction.

Newton received many honors, among which was election as a member of the Royal Society of London. He died in 1727 and was buried in Westminster Abbey.

Watt.—James Watt was born in Greenock, Scotland, in 1736. As a boy he gave evidence of ability and at the age of fourteen constructed an electrical machine. He learned the trade of making mathematical instruments and became so proficient that he was appointed instrument maker to the University of Glasgow.

Later he became distinguished for improvements in connection with the Newcomen engine, a machine used in pumping water from mines by means of steam power, invented by a blacksmith named Thomas Newcomen. His inventions so improved this machine that it generated much greater power with the use of less fuel. By the employment of a connecting rod and crank shaft he

succeeded in changing the back-and-forth motion of the piston of this engine to a rotary motion, and this made the steam engine applicable as a motive power for all kinds of machinery. Today the steam engine is used for many purposes, such as driving the machinery of ships, railway engines and manufacturing plants of all kinds. In a comparatively short time the development of the steam engine revolutionized most lines of industry.

Watt's patents included a number of inventions connected with the steam engine, including the steam gauge and the water gauge.

In 1775 he became a partner in a firm for the manufacture and sale of steam engines. He retired from business in 1800 and died in 1819. A statue was erected to his memory in Westminster Abbey by national subscription.

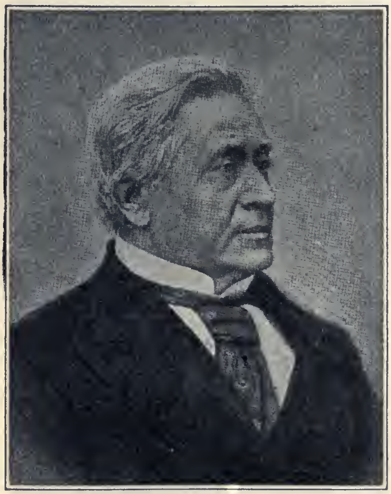
Faraday.—Michael Faraday was born near London in 1791, the son of a blacksmith. His schooling was very scanty. At twelve years of age he became errand boy to a bookbinder, and later his apprentice. He read some of the books he bound, finding special interest in articles on chemistry and electricity. These articles stimulated him to self-education. He performed experiments and attended evening lectures on science (then called philosophy). The chemist, Sir Humphrey Davy, perceiving his ability in chemical and electrical research, engaged him as secretary and traveling companion. Through this patron, he was appointed to the Royal Institution of Great Britain. He presented before that body a long series of scientific papers which enriched the research work of the Royal Institution.

Brown Brothers.

MICHAEL FARADAY
Discovered induced electricity.

Faraday discovered that a magnet moved within a coil of wire will start a current of electricity flowing through the wire. This discovery led to the great dynamos and generators which today supply practically all of our electricity. His experiments with glass and the electromagnet helped the art of making optical lenses. He died in 1867.

Henry.—Joseph Henry was born in Albany, New York, in 1797. He received his education in the public schools and in the Boys Academy of his native city, and at the age of twenty-seven became professor of mathematics in the academy. Here he experimented in electricity and electromagnetism, and made discoveries of the greatest importance in the development of these phases of science.



JOSEPH HENRY
Made many discoveries relating to induced electric currents.

Oersted's discovery, a few years before, of the relationship existing between electricity and magnetism had aroused world-wide interest, and all progressive physicists were engaged in making investigations along these lines. Henry was one of the men most interested. He discovered the principle of electromagnetic induction about the same time that Faraday did, although he did not publicly announce it. This discovery was one of the most important in the history of science. From it has developed most of the modern applications of electricity. He demonstrated that the number of turns in the wire of an electromagnet as well as the amount of current passing through its coils had much to do with its magnetic strength. He also showed that by binding the magnet with many turns of fine wire it was possible to make up for the loss of current,

due to the resistance of the intervening circuit when bringing an electromagnet into use at a great distance. The successful demonstration of this principle was a forerunner of the development of the electric telegraph.

Henry prepared a device, operated by a current sent through a long line of insulated wire, for making signals at a distance by electromagnetism, and made interesting inventions for other purposes. One of his electromagnets made for Yale college sustained a weight of over a ton. He also succeeded in producing an electric spark by means of purely magnetic induction. Together with Faraday he laid the foundation for the modern study and development of electromagnetism and electrical induction.

In 1832 Henry was elected professor of natural philosophy at Princeton. In 1846 he was chosen first secretary of the Smithsonian Institution at Washington, a position he held until his death in 1878. In 1849 he was elected president of the American Association for the Advancement of Science, and in 1868 president of the National Academy of Sciences. He received many other honors.

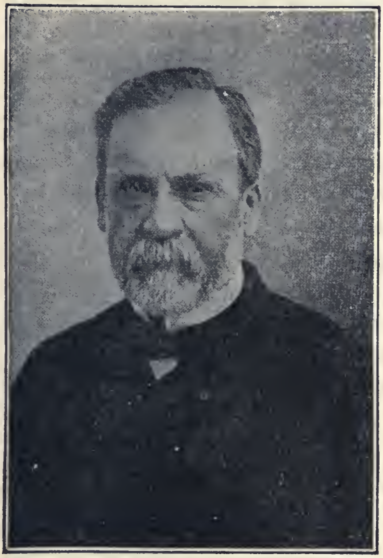
Joule.—James Prescott Joule was born at Safford, England, in 1818, the son of a brewer. He studied at home and was for the most part self-educated, although he received for some time three lessons a week from the distinguished chemist, John Dalton. He became interested in physics and made original researches in his home laboratory.

At the age of nineteen Joule constructed an electromagnetic engine. He emphasized the importance of accurate measurements in scientific work. He formulated the laws of the heating effects of electric currents in a conductor. Working with Lord Kelvin, he made important discoveries regarding the heat properties of gases. His discoveries regarding the condensation of steam increased the efficiency of the steam engine.

His services to science were recognized in many ways. He was awarded the Royal medal of the Royal Society in 1852 and the Copley medal in 1860, and received degrees from several leading universities. He was elected to membership in all the principal scientific societies of the world and was chosen president of

the British Association for the Advancement of Science in 1873. He died in 1889.

Pasteur.—Louis Pasteur was born in Dole, France, in 1822. In his student days he made a special study of chemistry and took his degree in 1842, after which he was a professor for several years in different universities. In 1856 he received the Rumford medal of the Royal Society of London awarded for scientific attainment. Although distinguished in other kinds of work, it was in the field of bacteriology that he became eminent. In the study of the germ theory his greatest work was accomplished. He demonstrated that various specific diseases, both in animals and plants, were caused by different species of bacteria, and showed how these diseases may be prevented.



Louis Pasteur
His success in treating hydrophobia was one of his greatest triumphs.

Previous to 1856 the cause of fermentation was unknown, but in this year Pasteur proved that it was due to the action of yeasts and other tiny forms of plant life. This discovery enabled the wine makers of France to overcome certain kinds of fermentation which were ruining their wine, by destroying with heat the plant cells which caused them. Later Pasteur discovered that a disease which threatened to ruin the silk industry by attacking the silk worms was caused by bacteria, and he suggested an effective remedy. Thus his work led to the saving of vast sums of money, not only to the people of France, but also to the people of other countries engaged in these industries.

Of still greater importance to humanity was the application of his discovery to the prevention of disease in man. By injecting

a small amount of a diluted virus, produced by making a succession of pure cultures of a certain disease-causing virus, into an animal, he found that the animal, after having a mild attack, was thereafter immune to that disease. The success of this method was first shown in the prevention of chicken cholera and of splenic fever in cattle. The same method is now successfully used to combat disease in man by the employment of serums, vaccines and antitoxins.

The cure for hydrophobia, or rabies, was one of Pasteur's greatest triumphs. At the Pasteur Institute in Paris, named in honor of this great biologist, several thousand cases of rabies have been successfully treated. Among other diseases for which remedies have been discovered at this institute are diphtheria, lockjaw, and bubonic plague. He died in 1895.

Jenner.—Edward Jenner was born at Berkeley, Gloustershire, England in May, 1749. After the completion of his preliminary education, he was instructed in the elements of surgery by a distinguished surgeon, and at the age of twenty years he went to London where he continued his professional studies with Dr. John Hunter, a noted physician. He received the degree of M. D. from the University of St. Andrews, Scotland, in 1792. Returning to his native town he practiced his profession successfully.

Edward Jenner
Discoverer of vaccination against smallpox.

Having learned that the peasants of Gloustershire believed that accidental cowpox caught while milking cows was a preventive of the scourge of smallpox, he began a series of experiments to determine whether this belief had a basis of truth. As a result of his experiments, he decided the belief had such a

basis and published an article explaining the favorable effects, as a preventive of smallpox, of a virus known as vaccine, derived from the cow. He soon became famous as the discoverer of vaccination to prevent smallpox.

Although this method met with great opposition it was soon accepted throughout the civilized world and is generally regarded as a great blessing to mankind. On account of his discovery he was elected an honorary member of many learned societies in Europe. The latter part of his life was spent in spreading knowledge of vaccination. He died at the age of 75.

Darwin.—Charles D. Darwin was born in England, February 12th, 1809. He was educated in a private academy and later went to Edinburgh University where he discovered that his real interest lay in natural history. He made many field trips with the University professors and so began his real contact with nature. Later he entered Cambridge with the idea of becoming a clergyman, but fell under the influence of Henslow, a noted biologist, and again found his interest strongly turned to the field of nature.

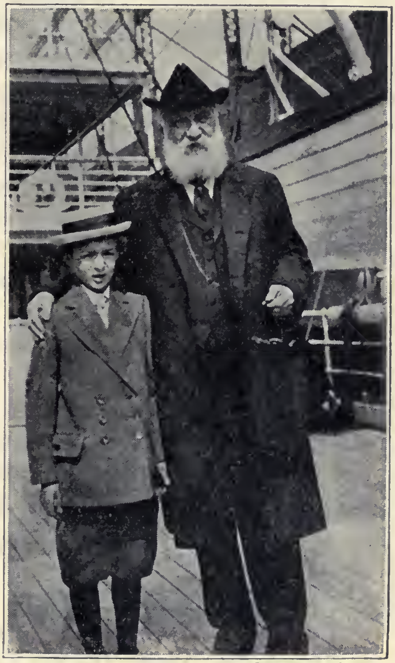
In 1831 he joined an expedition to South America and investigated the flora and fauna of many sections of that continent. Several years were spent in the study of plant and animal life, both in these localities and during a voyage around the world.

Darwin became an authority on many phases of nature. He made some exceptional studies of the social habits of ants and bees. He disclosed to the world the great economic importance of the earthworm as a fertilizer and worker of the soil. Finally after many years of study and research, he gave to the world his theory of how species of animals change and develop new characteristics. He made many other highly important contributions to science and was considered one of the great scientists of his time. Darwin received honors and recognition from the chief scientific societies of the world. He died in 1882.

Lister.—Joseph Lister was born at Upton, England, in 1827, and was educated in London. He studied medicine, and in 1855 secured a fellowship in the Royal College of Surgeons of Edinburgh. After completing his course he taught surgery with great

success in the University of Glasgow and later in King's College, London.

Lister is especially noted for the successful introduction of the antiseptic method in surgery which reduced the dangers of infection following operations. This took place in 1867 while he was teaching in the University of Glasgow. This method led to the aseptic method now used the world over, in which operations are performed under sanitary conditions, free from living germs. Lister received honorary degrees from both Oxford and Cambridge, and was made a baronet in 1883. He wrote several books bearing on the antiseptic system of treatment. He died in 1912.



Brown Brothers.

ALEXANDER GRAHAM BELL
He invented the telephone.

Bell.—Alexander Graham Bell was born in Scotland in 1847. He was descended from a line of specialists in the human voice. His grandfather invented a system to correct stammering; his father was an authority on elocution and also the inventor of a system of sign language for deaf mutes.

Alexander Graham Bell early showed both interest and ability in the same field. While still a boy he constructed an artificial skull, which, when operated by a pair of bellows, would pronounce certain words. He was educated in Edinburgh and London and afterwards taught elocution for a time in England. Later he came to America for his health. Here he continued certain experiments which gradually led him to consider the problem of transmitting human speech through space. He studied a human

ear, obtained from a physician, and finally developed the idea of making the metal disc diaphragm so vital in the modern telephone. While experimenting with Thomas Watson in Boston in 1875 he discovered the secret of sending sound over wire and the telephone "talked" for the first time, although the voice was carried only from one floor to another.

The telephone was exhibited at the Centennial Exposition in Philadelphia in 1876 but attracted little attention until Don Pedro, Emperor of Brazil, took it up and expressed astonishment at what it did. Immediately the telephone became a feature of the Exposition, but for a time people generally did not realize its commercial importance. Within a year, however, 778 telephones were in use. Then the Bell Telephone Company was formed and the commercial use of the instrument really began. Now there are many millions of telephones in the United States alone, and improvements in telephone communications have made it possible to talk across the entire country or under the ocean to foreign lands. Bell's telephone patent is considered the most valuable patent ever issued.

While Alexander Graham Bell's greatest contribution to science and to modern life was the telephone, he made other inventions and showed a wide interest in other fields of science, including geography. In his later years he was deeply interested in the conquest of the air and carried on many experiments in that field, including the use of kites. He died in 1922.

Burbank.—Luther Burbank was born in Lancaster, Mass., on March 7th, 1849. He was educated in the local schools and then spent a few years working in his uncle's plow factory. From early boyhood, however, his real interest was in growing things. For a time he devoted himself to market gardening and during this period he developed a new species of potato, which was given his name and which has added materially to the prosperity of farmers.

While still a young man Burbank moved to Santa Rosa, California, and there established an experimental farm. He quickly developed remarkable skill in the selection and cross-

breeding of plants. He not only greatly improved existing varieties, but succeeded in developing many new plants which proved of great economic importance. While he was called a "wizard" of the plant world, there was little mystery in his methods of work for he secured his results by the use of established scientific laws and by following closely nature's own methods.

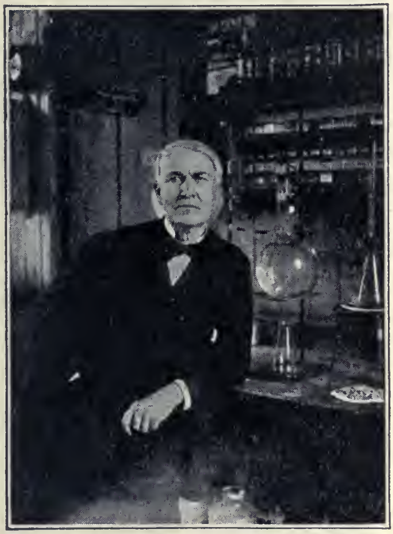
Brown Brothers.

LUTHER BURBANK
He developed wonderful new plants.

While Luther Burbank markedly improved the quality of many well-known vegetables and fruits, including the development of corn that grows to a height of 18 feet, he also is responsible for the Iceberg, an improved white blackberry, for the plumcot, a new fruit obtained by crossing the apricot and the plum, for the giant Shasta daisy and for other new food and ornamental plants. While devoting himself largely to certain fields of growing things, he was an intense lover and student of nature in all its phases. He died in 1926.

Edison.—Thomas Alva Edison, the well-known inventor, was born at Milan, Ohio, February 11th, 1847. His mother taught him to read but beyond that he had practically no early education. While still quite young he went to work as a newsboy on the Grand Trunk Railway. During this period he studied in his spare moments, experimenting with chemicals and also learning printing. He edited and printed a small newspaper, being permitted to run his press in one corner of the baggage car. This newspaper he sold on the train.

When 16 years of age, through the assistance of a station master whose child he had rescued from danger, Edison secured employment as a telegraph operator of the Western Union Telegraph Company. Even at this age he was more interested in working out improvements on his telegraphic instrument than in sending and receiving the messages that came to the office.



Brown Brothers.

THOMAS A. EDISON
A great inventor in many fields.

After a time his increasing skill in inventing led to the establishment of his first laboratory at West Orange, New Jersey. Here by degrees he gathered together and directed a body of experimenters. He made "experimenting to invent" an established art.

Edison himself has always been a tireless worker. In all probability he has made more inventions than any other man and very many of them have added materially to our comfort and pleasure. We owe to him the modern electric light, on which he spent an immense amount of labor, involving endless experiments and world-wide searches for materials. We owe to him the phonograph, the motion picture machine, the storage battery, important improvements in the telegraph and telephone and typewriter, and the perfection of the electric motor that runs our street cars. He died in 1931.

Madame Curie.—Most prominent among women who have distinguished themselves in scientific research is Madame Curie. She was born at Warsaw, Poland, in 1867. Her parents were teachers in the secondary schools of the town. The family name was Sklodowska. She was a very promising student and was educated in her native town and at the Sorbonne in Paris, where

she received the degree of Doctor of Science. In 1895 she married Pierre Curie, a professor of physics in this school, and together they spent much time in scientific research.

About this time many scientists were engaged in following up the research work of Henri Becquerel, a noted French scientist, who had discovered that the mineral uranium and its compounds possessed the property of throwing out rays which were able to enter into opaque objects and to act on photographic plates in a way similar to X-rays. It was found that this property of uranium remained even when its compounds were kept in darkness for several months. The question was whence came this energy constantly given off by uranium compounds.

Brown Brothers.

MADAME CURIE
She discovered radium.

Madame Curie, among other scientists, became greatly interested in this phenomenon and determined to make investigations of it. Accordingly she examined all the known elements and discovered that compounds of thorium were the only ones that would give off rays similar to those of uranium. She proposed the term *radio activity* for this newly discovered property of matter, and the term has been generally accepted.

At this stage, her husband, Pierre Curie, became interested in the search for this unknown substance. Abandoning other work, he joined her, and together they continued their investigations for several years. Having observed that pitch blende, the crude ore from which uranium is obtained, was more radioactive, that is, capable of giving off stronger rays than uranium, they suspected there was an unknown element in pitch blende which caused this.

They examined several tons of this substance and finally succeeded in extracting from the whole mass about one-half a teaspoonful of a substance which was many times more radioactive than uranium. This substance, owing to its remarkable power of radiation, was called radium.

The discovery of radium is regarded as one of the greatest scientific discoveries of the century. Its influence on the future development of physics and chemistry cannot be over-estimated. Honors and prizes for the discovery of radioactive elements were awarded jointly to Madame Curie and her husband. Among the honors was part of the Nobel prize for physics.

In 1906 Pierre Curie was killed in an accident and Mme. Curie succeeded him as professor of physics and director of the physical laboratory at the Sorbonne. In 1911 she was awarded the Nobel prize for chemistry. She died in July, 1934.

The Wrights.—While many scientists have had important parts in developing aerial navigation and in giving us a certain conquest of the air, undoubtedly special recognition should be given to two brothers, Wilbur and Orville Wright, who built and flew the first practical airplane. These brothers, one born in 1867 and the other in 1871, were interested from boyhood in flying things. While still children, they experimented with a flying toy and then with kites and that, by easy steps in the years that followed, led them, through the construction of gliders, to the airplane. A bicycle shop, which they owned together at Dayton, Ohio, supplied them with the funds necessary for experimentation in their chosen field.

They invented gliders sufficiently strong and well balanced to remain in air and to support a passenger. They studied the flights of birds, and the scientific experiments of men like Langley whose discoveries had made ultimate success possible.

From 1900 to 1903 the brothers continued experiments at Kitty Hawk, N. C., with gliders and kites. Then, in December 1903, they finished their first power air machine, which actually flew for 59 seconds. By degrees as improvements were worked out, flights of longer duration followed, one lasting over an hour and marked by a speed of over 40 miles per hour.

By thorough, systematic study and experimenting, these men, with very little early training, became modern scientists, whose names stand high in the list of those who have made possible the conquest of the air which is now an accepted fact. Until the death of Wilbur Wright in 1912, their work was always done together.

Michelson.—Dr. Albert A. Michelson, a native of Germany, was born in 1852. When a child, he, with his parents, moved to California where he prepared for college in San Francisco. He later entered the United States Naval Academy from which he was graduated in 1873, but continued there as an instructor in physics and chemistry until 1879. During the years 1880 to 1882 he studied at Berlin, Heidelberg, and Paris. On his return from Europe, he was appointed to the faculty at the Case School of Applied Science at Cleveland, Ohio, and later at Clark University, at Worcester, Massachusetts. In 1892 he went to the University of Chicago to teach.

Brown Brothers.

ALBERT A. MICHELSON
He made many valuable discoveries about light.

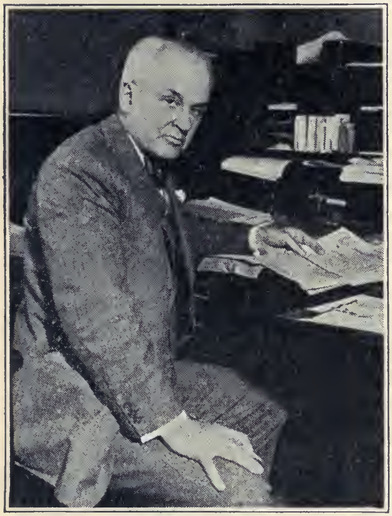
Throughout his career Dr. Michelson carried on research work incessantly. His greatest field of work was in light. His measurement of the velocity of light is the most accurate known. The methods he used, as well as his equipment, were of his own invention.

During the World War he returned to the naval service where several of his inventions, especially a range finder, became regular naval equipment.

After the war Dr. Michelson applied his knowledge of light to the study of astronomy, and discovered a method for measuring the diameter of stars.

He has written many books and papers and received various honors, chief of which was the 1907 Nobel prize in physics. He died in May, 1931.

Millikan.—Robert Andrews Millikan is noted as an outstanding experimenter. He was born at Morrison, Illinois, in 1868. After his graduation from Oberlin College, he continued his education at Columbia University and the Universities of Berlin and Göttingen in Germany. He later joined the teaching staff at the University of Chicago where he became professor of physics. In 1921 he became director of the Norman Bridge Laboratory of Physics at Pasadena, California, and chairman of the executive council of the California Institute of Technology.



Brown Brothers.

Robert A. Millikan
He discovered that all electrons are alike.

Independent of his work as a teacher, Dr. Millikan has done a great amount of scientific research. One of the problems in which he became deeply interested was the nature of the electron. He proved that all electrons are alike, and his observations of the electron have been the most accurate of any yet made. He has devoted a large amount of time to a study of the cosmic rays, a little-known form of radiant energy, of unknown source, which comes to the earth from somewhere in the space beyond our atmosphere.

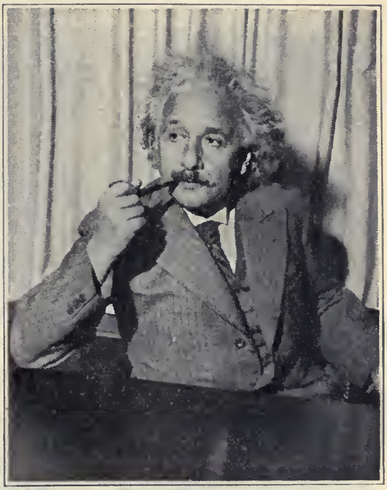
Dr. Millikan was awarded the Nobel prize in 1923 for his work in physical research.

Einstein.—One of the most famous of physicists is Albert Einstein. Born of Jewish parents in 1879, his life up to 1933 was spent in Germany and Switzerland. He spent his boyhood days

until 1894 in Munich, when he went to Switzerland for his college education. He did considerable teaching there and was made a Swiss citizen when he became Examiner of Patents at Berne.

Dr. Einstein was appointed head of the physics department at Prague in 1911. In 1913 he was called to Berlin to become the director of the Kaiser-Wilhelm Physical Institute. Among the many honors he has received both at home and abroad is the 1921 Nobel prize for distinguished work in physics.

Dr. Einstein has become most widely known for his work on relativity (the relation of space and time) but his contributions to science have been so varied that it is impossible to single out his most important work.



Brown Brothers.

Albert Einstein
His theory of relativity is the best known of his many scientific works.

Langmuir.—Irving Langmuir was born in Brooklyn in 1881. He was educated at Columbia University and at the University of Göttingen. Later he taught chemistry for three years at Stevens Institute of Technology, Hoboken, New Jersey, before taking up work in the research department of the General Electric Company at Schenectady.

Langmuir's first invention of note was the gas-filled electric light bulb. In the early bulbs the filament was placed in a vacuum within the bulb. One disadvantage of this light was that the inner surface of the glass darkened on use and as a result its lighting efficiency was lessened. Dr. Langmuir discovered that bulbs when filled with the gases nitrogen or argon did not blacken, and thus the gas-filled bulb came into general use.

It was largely due to his work that we have the vacuum tube,

which is used both in the broadcasting and receiving sets of our modern radio.

Dr. Langmuir has won many medals and prizes for his brilliant research work, one of which was the 1932 Nobel prize in chemistry.

Brown Brothers.

ARTHUR H. COMPTON
He has made valuable discoveries concerning the earth's rotation, heat, X-rays, and cosmic rays. The instrument he is adjusting is a device for measuring the intensity of cosmic rays.

Compton. — Among the younger scientists, few are giving greater promise than Arthur H. Compton, who was born in Wooster, Ohio, in 1892. After graduating from the College of Wooster, he entered Princeton University, where he received his Doctor's degree in 1916. He then became research physicist for the Westinghouse Electric Company, of Pittsburgh.

In 1923 Dr. Compton went to the University of Chicago where he has made valuable investigations concerning the earth's rotation, heat, X-rays and the cosmic rays.

Other Scientists. — The scientists about whom you have just been reading are only a few of the many who have labored hard and successfully to add to man's knowledge and to make his life better, safer, and more comfortable. In all of the branches of science, men and women are constantly searching for new facts and constantly striving to find better ways of doing things. In the table on pages 575-578, you will find the names and some of the achievements of many of the world's leading scientists. As you read the table, notice the various fields of science in which these people have worked. If any scientist in the list appeals to you particularly, you may find it interesting to read more about him.

NOTED SCIENTISTS

(For key to pronunciation, see page 614)

Name	*Dates*	*Outstanding Contributions*
Agassiz, L. (ăg'*á*-sē)	1807–1873	Author of many notable works on zoölogy and geology.
Ampere, A. (äm-pâr')	1775–1836	Made valuable discoveries concerning the relation between magnetism and electricity.
Bacon, F.	1561–1626	Originated the modern method of scientific study.
Bell, A. G.	1847–1922	Invented the telephone.
Bessemer, Sir H. (bĕs'ē-mẽr)	1813–1898	Invented the first practical method of making steel.
Black, J.	1728–1799	Discovered and measured the "latent heat" given off by substances when changed from liquid to solid, or gas to liquid.
Bunsen, R. W. (bo͝on'sĕn)	1811–1899	Discovered how to analyze light. Invented the Bunsen burner and other laboratory devices.
Burbank, L.	1849–1926	Developed many wonderful new plants.
Cavendish, H. (kăv'ĕn-dĭsh)	1731–1810	Discovered the composition of water.
Compton, A. H. (kŏm'tŭn)	1892–	Made valuable discoveries concerning the earth's rotation, heat, X-rays, and cosmic rays.
Crookes, Sir W. (kro͝oks)	1832–1919	Discovered thallium. Invented a new method of separating silver and gold from their ores. Invented the radiometer.
Curie, M. (kū-rē')	1867–1934	Discovered radium.
Cuvier, G. C. L. F. D. (kū-vyā')	1769–1832	Classified animals according to their internal structures.
Darwin, C.	1809–1882	Made many discoveries about the habits of animals, and produced a theory to explain how animals change and develop new characteristics.
Dewar, J. (dū'ẽr)	1842–1923	Invented the vacuum bottle. First to liquefy and solidify oxygen, hydrogen, and air.

Name	*Dates*	*Outstanding Contributions*
Edison, T.	1847–1931	Invented the electric light and many other useful devices.
Ehrlich, P. (ĕr'lĭk)	1854–1915	Improved the method of producing serum.
Einstein, A. (īn'stīn)	1879–	Made many discoveries in various fields of science. Author of the theory of relativity.
Fabricius, H. (fȧ-brĭsh'ĭ-ŭs)	1537–1619	Discovered that the veins have valves.
Faraday, M. (făr'ȧ-dā)	1791–1867	Discovered a method of inducing an electric current.
Galen, C. (gā'lĕn)	130–201	Discovered importance of pulse. Father of dissection and physiology.
Galileo, G. (găl-ĭ-lē'ō)	1564–1642	Invented the thermometer. Made many discoveries in astronomy and physics.
Gay-Lussac, J. L. (gā-lü-sȧk')	1778–1850	Discovered that gases combine with each other in certain fixed proportions to form compounds. Made many discoveries about the expansion of gases.
Haller, A. von (häl'ēr)	1708–1777	Wrote the first authoritative treatise on physiology.
Halley, E. (hăl'ĭ)	1656–1742	Discovered Halley's comet. Made discoveries concerning movements of stars and of the moon.
Harvey, W.	1578–1657	First to demonstrate the circulation of blood in the body. The father of embryology.
Helmholtz, H. L. F. von (hĕlm'hōlts)	1821–1894	Gave the first clear statement of the law of the conservation of energy.
Henry, J.	1797–1878	Made many discoveries relating to induced electric currents and to the use of electromagnets.
Herschel, Sir J. F. W. (hûr'shĕl)	1792–1871	Improved the telescope and made important astronomical discoveries.
Huxley, T. H. (hŭks'lĭ)	1825–1895	Made valuable discoveries in zoölogy.
Jenner, E.	1749-1823	Discovered that smallpox can be prevented by vaccination.
Joule, J. P. (joul)	1818-1889	Made important discoveries concerning the heat properties of gases and the condensation of steam.

Name	*Dates*	*Outstanding Contributions*
Kelvin, Lord (kĕl′vĭn)	1824–1907	Engineer in charge of laying the first Atlantic cable. Formulated a theory as to the age of the earth. Made researches which strengthened the molecular theory.
Kepler, J. (kĕp′lẽr)	1571–1630	Discovered the way planets move.
Koch, R. (kôk)	1843–1910	His researches in bacteriology greatly benefited mankind. Discovered the bacillus of tuberculosis.
Langmuir, I. (lăng′mūr)	1881–	Improved incandescent bulbs and radio tubes.
LaPlace, P. S. (lȧ-pläs′)	1749–1827	Substantiated Newton's law of gravitation by scientific experimentation.
Leeuwenhoek, A. Van (lā′vĕn-ho͝ok)	1632–1723	First to study blood capillaries, red corpuscles, and microörganisms with the aid of a microscope.
Liebig, J. Baron, von (lē′bĭk)	1803–1873	Made valuable applications of chemistry to agriculture and to food. Greatly advanced chemistry.
Lister, J.	1827–1912	Invented the antiseptic method of surgery.
Michelson, A. A. (mī′kĕl-sŭn)	1852–1931	Made many valuable discoveries about light.
Millikan, R. A. (mĭl′ĭ-kȧn)	1868–	Discovered that all electrons are alike.
Muir, J. (mūr)	1838–1914	A pioneer in advocating forest conservation and national parks.
Newton, I.	1642–1727	Discovered the theory of universal gravitation.
Pasteur, L. (pȧs-tûr′)	1822–1895	Discovered that fermentation and many diseases are caused by bacteria, and found methods of overcoming these bacteria.
Priestly, J. (prēst′lĭ)	1733–1804	First to produce oxygen and study it as a separate gas.
Pupin, M. I. (pû-pēn′)	1858–	Made electrical discoveries that increased the range of the long-distance telephone.
Ramsay, Sir W. (răm′zĭ)	1852–1916	Discovered argon, neon, krypton, and xenon gases. First to discover the presence of helium in a substance on earth.

Name	*Dates*	*Outstanding Contributions*
Rumford, B. T., Count (rŭm′fẽrd)	1753–1814	First to recognize heat as a form of motion. Improved design of fireplace and chimney.
Scheele, K. W. (shā′lẽ)	1742–1786	Advanced the science of chemistry. Discovered chlorine, glycerine, baryta, tartaric acid, and prussic acid.
Steinmetz, C. P. (stīn′mĕts)	1865–1923	Great expert in the improvement of electrical devices.
Stiles, C. W.	1867–	Discovered hookworm in southern United States.
Virchow, R. (vûr′chow)	1821–1902	Discovered the cellular structure of organs and tissues, and how cells reproduce. Applied this knowledge to the treatment of disease.
Watt, J.	1736–1819	Invented the first practical steam engine.
Wright, Orville	1871–	Invented the airplane.
Wright, Wilbur	1867–1912	Invented the airplane.
Zeppelin, F., Count von (tsĕp-ĕ-lēn′)	1838–1917	Developed the dirigible balloon.

Fact and Thought Questions

1. Define: (a) scientist; (b) inventor.
2. Name some great scientist living today. What is his field of science?
3. Mention some great invention made within your lifetime. By whom was it made?
4. Could there be great practical inventions if there were no scientists? Why?
5. Who of the scientists discussed in this chapter developed methods of scientific research that have greatly helped other scientists?
6. Who of the scientists discussed were also practical inventors?
7. State some ways in which the work of one scientist may help another.
8. Tell all you can about Francis Bacon.
9. Complete these statements:
   (a) Bell invented the ——.
   (b) The phonograph was the invention of ——.
10. What scientific services have been rendered by James Watt? Isaac Newton? James Prescott Joule? The Wright Brothers? Dr. Albert A. Michelson? Robert A. Millikan? Albert Einstein? Irving Langmuir? Arthur H. Compton?
11. What invention of Galileo is a common household appliance?
12. Edward Jenner's great discovery has led to what common health regulation?
13. Who of the other scientists mentioned have contributed to the proper treatment of disease?

14. Name several ways in which the discoveries of chemical laws have affected our daily lives.
15. Who of the scientists discussed in this chapter were self-educated? Who were specially trained? Why is special training of value?

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CHAPTER XLVI

NEW DEVELOPMENTS IN SCIENCE

The forward progress of Science never stops. Thousands of scientists are constantly experimenting to learn new things and to develop better ways of doing things. Almost every day, important discoveries and inventions are made in the various fields of science.

Most of us never know about many of the inventions and discoveries which affect us. A scientist may discover a way of making better electric-light bulbs. Perhaps we never hear of his discovery, but our homes are lighted better because of it. Other inventions and discoveries are so important that everybody hears about them and marvels at them.

In this chapter we are going to learn about some of the more important and interesting of the very recent inventions and discoveries which help to make our lives safer and more comfortable.

The Autogiro.—While the airplane has now been developed to a high state of efficiency, it has certain disadvantages. In taking off and landing, airplanes must travel across the ground at rapid speed. There is, therefore, the possibility of accident at the beginning and end of each flight. Because they must also travel along the ground for some distance both in taking off and alighting, and because they cannot rise at a steep angle, ordinary airplanes require large flying fields. In recent years a new type of plane, called the autogiro, has been developed which does not have these disadvantages.

In the autogiro a large four-bladed wheel, sometimes called the "windmill," is mounted horizontally on top of the body. The windmill furnishes the chief support of the machine while in the air, taking the place largely of the wings of an airplane. Some autogiros have small wings, which act more as balancers than as planes to hold up the machine. Some of the more recent models have no wings at all.

Publishers' Photo Service.

AN AUTOGIRO IN FLIGHT
This machine has small wings which act as balancers. Other types have much smaller balancers, and some have none at all. Note the large size of the "windmill," which holds up the machine.

The autogiro is driven forward by a vertical motor-driven propeller mounted in front, in the same way as the airplane is propelled. The windmill which holds up the autogiro is not driven by a motor but is turned by the force of the wind as the machine moves through the air. In some types the turning of the windmill is started by power from the motor, but as soon as the autogiro begins to move forward the motor is disconnected from the windmill and the force of the air turns it. The autogiro can take off and land at very slow speed and can rise and descend at a steep angle. It therefore does not require a large landing field. Besides being able to start and land within a small area, the autogiro is not dependent upon rapid forward motion to keep it up, as the airplane is, for the windmill exerts great lifting power even at slow speed. Another advantage of the autogiro is that it can usually land safely if the engine stops in mid-air, because the windmill continues to turn and thus supports the machine as it settles to the earth. As the autogiro comes into wider use, it should give us more safety in air-travel and should enable avia-

tors to take off and land on small fields close to centers of population, instead of on large aviation fields located miles away from these centers.

Infra-red Rays.—What would you think of a man who went out to take pictures in a heavy fog? "You're wasting your time," you might exclaim. "Why, in a fog like this you can't even see across the street, to say nothing of taking pictures!" Yet the man might soon return with pictures as clear as those taken in bright sunlight. How is this possible?

White light, you remember, can be broken up into the seven primary colors—red, orange, yellow, green, blue, indigo, and violet. The red rays have the longest wave length and the violet rays have the shortest. There are other similar rays whose wave length is so short or so long that they cannot be seen by the human eye. Those rays whose wave length is shorter than the wave length of violet light are called *ultra-violet rays.* Those rays whose wave length is longer than the wave length of red light are called *infra-red rays.*

One of the most interesting uses of infra-red rays is in the photographing of distant objects. Fog and dust particles in the air interfere with the passage of ordinary light rays, but they have little effect on infra-red rays. By the use of photographic plates and lenses specially adapted to take advantage of infra-red rays, clear pictures can be taken of distant mountains and other objects so far away that they are quite invisible to the naked eye. Pictures may also be taken in foggy weather and even in the dark by making use of infra-red rays.

The Photoelectric Cell.—A man drives his automobile toward his garage, and magically the doors open without the touch of a human hand. A burglar kneels in front of a safe, and before he touches the handles of the door an alarm rings in the nearest police station. A thousand cars pass through a tunnel and are accurately counted even though no one may be there to see them pass. These are but a few of the many marvelous things done by the new "electric eye."

The real name of the electric eye is the *photoelectric cell.* In appearance, the photoelectric cell looks much like an ordinary

electric-light bulb. It is coated on the inside with a layer of mercury, to keep out light, and a layer of potassium, which is very sensitive to light. On one side of the bulb is a small, round "window" of clear glass, without either the mercury or the potassium coating. In the center of the bulb is a filament consisting of an upright metal ring connected by a wire to the base of the cell.

In use, the photoelectric cell is connected in a circuit, with the filament joined to the positive pole of a source of electricity and the potassium lining of the bulb joined to the negative pole. A special lamp is adjusted to send a beam of light through the clear glass "window" into the cell. When the lamp is not turned on, and the cell is in darkness, no current flows between the filament and the potassium lining. But when a beam of light from the lamp enters the cell through the round window of clear glass, it causes the potassium lining to give off electrons, and a current of electricity passes between the filament and the potassium lining. The stronger the beam of light, the more powerful is the current of electricity which flows through the circuit.

Today, the photoelectric cell has a great many uses. Astronomers use it to measure the intensity of the light coming to us from the different stars, for it is so sensitive that it can detect differences in brightness not apparent to the human eye. It is used to count objects of all sorts. For example, on one side of the entrance of the Holland Vehicular Tunnel, which joins New York and Jersey City, there is a photoelectric cell used in an electric counting machine. On the opposite side of the tunnel is a lamp which sends a beam of infra-red light to the cell. As long as the light strikes the cell, a continuous current of electricity flows through the circuit. Every automobile that passes through the tunnel passes between the lamp and the cell, thus cutting off the beam of light, interrupting the current, and operating the counting machine. The photoelectric cell is used in burglar alarms. In one such device a special lamp sends an invisible beam of infra-red light across the front of a safe or across a doorway to a hidden photoelectric cell. When a person passes between the lamp and the cell, he cuts off the infra-red light and interrupts the electric current flowing through the cell. This rings a burglar

alarm attached to the cell. The "electric eye" is also used to detect slight differences in color, and it plays an essential part in talking motion pictures, in sending pictures by telegraph or radio, and in television. It will be interesting for you to find out how many new inventions have been made possible by this one useful device—the photoelectric cell.

Talking Motion Pictures.—What is the chief difference between the motion pictures of today and those of a few years

Brown Brothers.

PART OF A TALKING PICTURE FILM

Both the picture and the sound are recorded on this film. Notice the sound track at the left of the picture. The holes in the outer edges of the film fit over the teeth of a series of cog wheels which move the film through the motion-picture machine.

ago? Sound, of course. The actors in those days were seen but not heard. Today, we not only see the actors but hear their voices as well. How is this done?

Talking motion pictures are of two kinds. The simpler form consists of a series of phonograph records, made at the same time that the pictures are taken. The film registers what the actors do and the records register what they say, as well as any sound effects which are made to accompany the action. When the picture is shown, the records are played on a special electric phono-

graph which operates a loud speaker behind the screen. In this form of talking picture, the phonograph and the motion picture machine must be carefully adjusted so that each sound comes at exactly the right point in the picture.

The second form of talking picture is now much more widely used. In this type, the pictures and sounds are both recorded on the same film. The pictures are taken just as in silent motion pictures and the sounds are recorded on the film at the side of the pictures. As the film is run through the camera, a beam of light from a lamp passes through a narrow slit and falls upon this sound strip. A special shutter, operated by the sound waves of the actors' voices, varies the width of the slit through which the light passes, and thus regulates the amount of light which strikes the sound strip. When the film is developed, the sound strip appears darker in some places than others, according to the amount of light that struck it as it passed the slit.

When a film is shown, the sound strip passes between a lamp and a photoelectric cell. The varying darkness and lightness of the sound strip causes the beam of light passing through the film to the photoelectric cell to vary in brightness. This causes corresponding variations in the strength of the electric current which passes through the photoelectric cell and which operates the loud speakers behind the screen. In this way, the loud speakers are made to give out the same sounds that were recorded on the sound strip of the film when the moving picture was taken.

The next time you go to see a motion picture, stop and think of the wonderful way in which the sounds and the actors' voices are preserved and reproduced for your enjoyment.

Telephotography.—A civil war broke out in Austria. In a great apartment building in Vienna a group of armed revolutionists tried to defend themselves against the government soldiers. Bullets from rifles and machine guns crashed through the windows. Explosive shells ripped holes in the walls. The revolutionists were forced to surrender.

A few hours after the fighting was over, a New York paper printed a picture of the wrecked apartment house. How had that picture traveled three thousand miles so quickly? By boat and

Keystone View Company.

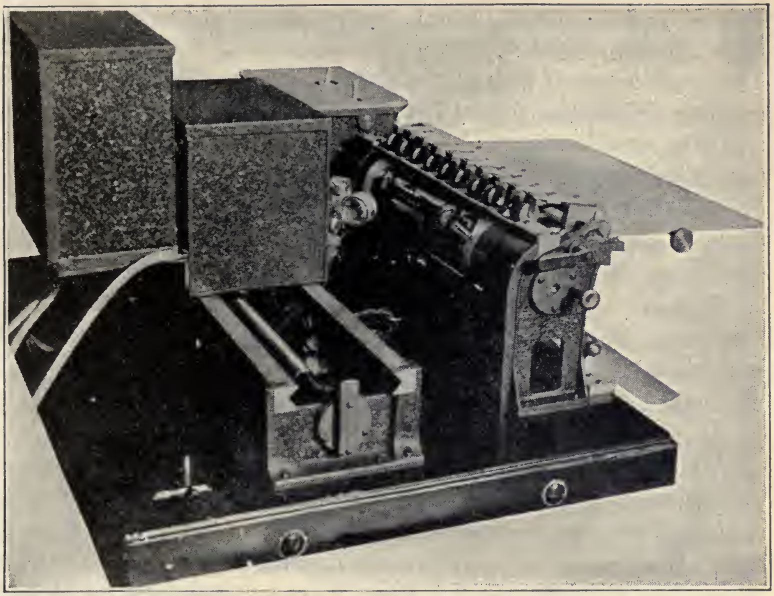
A PICTURE SENT BY TELEPHOTOGRAPHY

This picture shows the damage done to an apartment building in Austria during a civil war. The picture was sent by wire from Vienna to London and by radio from London to New York. Notice the blurred effect, a characteristic of pictures sent by telephotography.

train, it would have taken nearly a week. Magic? No, *telephotography!*

Telephotography is the sending of pictures by telegraph or radio. This is done with the help of a machine consisting of a revolving cylinder, a lamp, and a photoelectric cell. The picture to be sent is fastened to the cylinder, and a small beam of light from the lamp is focused on one corner of it. On some machines the cylinder is mounted on a spiral screw, so that as it revolves it also moves along the screw. In other cases the lamp and the photoelectric cell are mounted on a spiral screw and move along the screw as the cylinder revolves. The beam of light thus travels continuously over the surface of the picture until all parts of the picture have been illuminated.

As the cylinder revolves, the beam of light from the lamp is



Keystone View Company.

A Telephotograph Sending Apparatus

Notice the revolving cylinder at the right with the picture fastened to it. The light bulb and the lens focus a beam of light on one part of the picture after another. The photoelectric cell, to which the light is reflected from the surface of the picture, is located in the metal box at the left.

reflected from the surface of the picture to the photoelectric cell. Since more light is reflected from the light parts of the picture than from the dark parts, the amount of reflected light constantly varies and this causes variations in the strength of the electric current flowing through the cell. The varying electric current, greatly amplified by a series of vacuum tubes, is either sent by telegraph to the receiving apparatus or else flows through the aerial wires of a radio sending set and creates corresponding radio waves in the ether.

The receiving apparatus in telephotography is much like the sending apparatus. The varying electric current from the sending set, greatly amplified by a series of vacuum tubes, operates a special lamp filled with neon gas. As the current increases and decreases in strength, the neon lamp glows with a corresponding

brightness or dimness. The light from the lamp falls on a special photographic negative, very sensitive to light, which is fastened to a cylinder revolving at the same speed as the cylinder in the sending apparatus. As the lamp varies in brightness, the exposed negative records dark and light patches corresponding to the dark and light patches on the picture in the sending apparatus. The negative is then developed and a picture is printed from it, which is an almost exact reproduction of the picture in the sending apparatus.

The process of telephotography is still far from perfect. Pictures sent by wire or radio are usually somewhat blurred and can easily be distinguished from ordinary photographs. The next time you look through a newspaper, see if you can find any telephotographed pictures.

Television.—You sit down at your radio set, turn a knob or switch, twist a dial, and hear the voice of a person who may be hundreds or even thousands of miles away. A wonderful experience, which many of us have every day without stopping to think how really marvelous it is! Now, thanks to the work of skilled scientists, an even greater wonder is made possible. Not only can we *hear* the distant broadcaster, but, with the proper apparatus, we can also *see* him by a process known as *television.* The word television means "seeing at a distance."

The essential parts of a television sending set are a powerful lamp, a scanning disk, and two or more photoelectric cells. The person who is to be "seen" sits in front of the scanning disk, which is a circular piece of metal pierced by a spiral series of holes. Opposite him, beyond the disk, is the powerful lamp. The photoelectric cells are arranged nearby in such a position that any light which falls upon the face of the broadcaster is reflected to them.

In broadcasting, the scanning disk is whirled rapidly by an electric motor, and the light from the powerful lamp passes through the holes in the disk, falls on the face of the broadcaster, and is reflected to the photoelectric cells. As the first hole comes opposite the lamp, a brilliant beam of light passes through it and sweeps across the top of the broadcaster's face. As the second hole

comes opposite the light, another beam passes through it and sweeps across the broadcaster's face a little lower than the first beam. By the time the last hole has passed in front of the light, each part of the broadcaster's face has been lighted up brilliantly for a small fraction of a second. The scanning disk revolves several times a second, so each part of the face is lighted a number of times in every second, though only one small part is lighted at any one time. As the light is reflected to the photoelectric cells, the current flowing through them varies in strength depending upon the lightness or darkness of the part of the face being illuminated. This varying current is greatly amplified by a series of vacuum tubes, then flows through the aerial wires of the radio sending apparatus and sets up radio waves in the ether.

The most important part of the television receiving apparatus is a long glass tube filled with neon. The tube is bent back and forth in parallel rows to form a rectangular glass screen about two feet wide and two and a half feet high. Within the tube are 2,500 separate electrodes,[1] spaced at regular intervals. As the beam of light in the sending set sweeps across the upper part of the broadcaster's face and is reflected to the photoelectric cells, an electric current passes between the first and second electrodes, then between the second and third, the third and fourth, and so on, causing a series of tiny flashes. The brightness of each flash depends upon the strength of the varying electric current received by radio from the sending set. Thus, as the beam of light in the sending set sweeps over one part after another of the broadcaster's face, the various parts of the receiving screen light up brightly or dimly, depending upon the lightness or darkness of the corresponding parts of his face. So rapidly do the flashes occur that all 2,500 of them have taken place before the image of the first one has faded from the retina of the eye. Thus the observer sees a single, complete picture instead of a series of separate flashes. Each section of the tube flashes several times a second, so the retina of the eye beholds a continuously lighted picture of the broadcaster's face—a picture which constantly changes as the face changes its expression and position.

[1] See definition on page 623.

Although television is still in the experimental stage, wonderful results have already been achieved. It probably will not be many years before we can sit at home, seeing and hearing football games, plays, concerts, political meetings, and hundreds of other forms of entertainment and instruction.

Telephoning Across the Ocean.—Not long ago a business man in New York City wished to talk to a customer in Paris, Kentucky. He told his secretary to call long-distance and get a certain number in Paris. The secretary did as she was told, but to his great surprise the business man found himself talking to someone in Paris, France, instead of in Paris, Kentucky. This shows how easy it now is to telephone to Europe, even though there are no telephone wires across the Atlantic ocean.

How is this done? You pick up your telephone and tell the operator that you wish to call such-and-such a number in London, England, or else you give the name and address of the person whom you wish to call. Your connection is made, like any long-distance telephone connection, with a powerful radio station near New York City. The radio operator calls a certain station in Scotland which receives all messages intended for any point in the British Isles. He establishes clear radio communication with this station, using short radio waves. These short waves are not so long as the usual radio waves used in broadcasting, but they will carry farther.

When communication has been established, the American radio operator makes a connection between the telephone line and the radio sending set. Your telephone now serves as a broadcasting microphone, sending a varying electric current to the sending set, where it is amplified and sent through the aerial wires, thus setting up radio waves in the ether. These waves are picked up by the radio station in Scotland and turned back into a varying electric current, which is sent through telephone wires to the proper telephone receiver in London, England. Thus, through the medium of telephone and radio, you are able to talk to a person in Europe almost as well as to another person living within a few miles of your home.

Even passengers on ocean liners can now telephone to their

friends on shore by means of short-wave radio and the regular telephone lines.

Radio and Aviation.—A huge passenger plane roared across the flying field and swept up into the air. As it passed over the

Publishers' Photo Service.

HE HELPS MAKE FLYING SAFE

This radio operator is in constant contact with all passenger planes flying to or from the airport where he is stationed. He keeps the pilots informed concerning the weather and other important information and stands ready to send help in any emergency.

edge of the field a wheel came loose from the undercarriage and hurtled to the earth. The pilot of the plane did not know that the wheel was gone and that if he tried to make a normal landing at his next stop the plane would be wrecked. Yet before the plane was out of sight, a voice from the flying field told the pilot of his danger. As a result, he was able to make a skilful one-wheel landing at the next field, saving his passengers from injury and perhaps death. It was the magic voice of radio that saved the situation.

Radio is now used in many ways to make flying safer. The pilots of all big passenger planes are in constant radio communication with the different airports along their routes. At frequent intervals they receive detailed reports about the weather ahead of them, the height of the clouds, the condition of the landing fields, and other important information. They, in turn, keep the airport officials informed concerning their location, their course, and any difficulties which they may be experiencing.

The latest way in which radio helps aviation is through the use of radio beacons. These are automatic sending sets located at principal airports. By means of a special apparatus, each beacon sends out a continuous series of radio waves which make a steady buzz in the radio receiver of a plane flying directly toward the beacon. If the plane gets off its course and flies to the right of the beacon, the steady buzz breaks up and becomes a series of signals, - — - — - —. If the plane flies to the left of the beacon, the steady buzz breaks into a different series of signals, — - — - — -. Thus the pilot, by listening to the beacon signals and changing his course whenever the steady buzz breaks up into either series of signals, can manage to fly steadily toward his destination, even when he does not know where he is and is unable to see the ground or any familiar landmark.

Floodlighting and Searchlights.—In the early days of aviation, all flying had to be done by daylight. A pilot who was still aloft when darkness fell could not make a safe landing, for he could not see the ground. Now, all that is changed. Passenger planes make regular night trips from city to city, flying as safely as by day.

While radio plays an important part in making flying safe, the part that light plays is almost as important. A plane approaches an airport after dark. While still miles away, the pilot sees a flash of light far in the distance. Again and again comes the flash, at regular intervals, guiding the plane straight to the field. Then, as the plane circles and prepares to land, suddenly the entire field is bathed in a brilliant, even light which makes landing as safe as in broad daylight.

Two kinds of lights are used to make night flying safe—

Westinghouse Electric Company.

FLOODLIGHTS AT AN AIRPORT

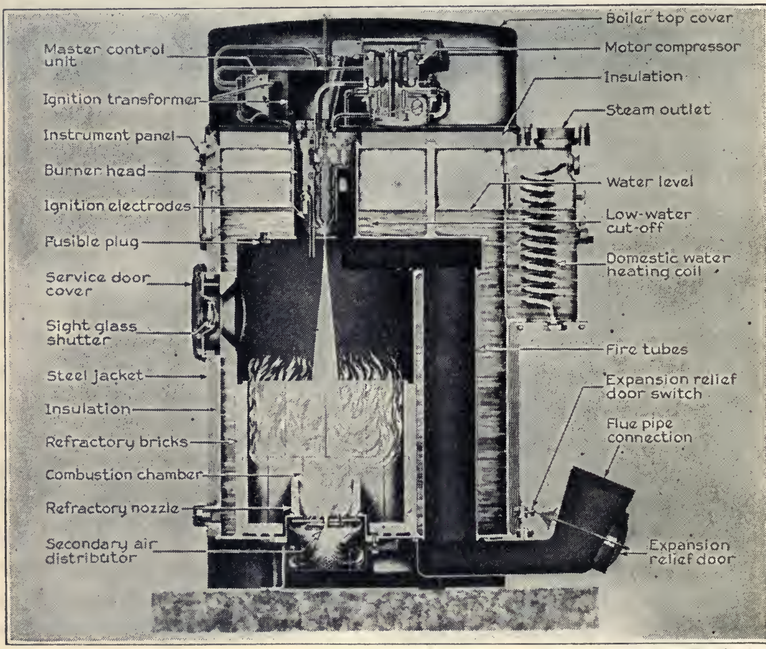
Floodlights are designed to spread their beams over a wide area. Notice how brilliantly the field is lighted up by these powerful lights.

searchlights and *floodlights.* A searchlight is a powerful lamp, usually an arc-light, which sends a narrow beam to a great distance. The light which guides planes to an airport is a searchlight, mounted on a tall steel tower and constantly turning about so that its beam sweeps in a great circle. Each time the light turns toward a distant pilot, he sees a flash of light. Some of the searchlights used in aviation are not arc-lights, but contain powerful incandescent bulbs. Such lights are usually equipped with automatic bulb changers, so that as soon as one incandescent bulb burns out it is at once replaced with another. Searchlights are also used on locomotives, automobiles, and ships, and wherever it is desirable to light up a small area brilliantly from a distance.

A floodlight is just the opposite from a searchlight. Instead of concentrating all its light into a powerful narrow beam, it spreads it out over as great an area as possible. The floodlights used in airports are especially designed to spread their beams over a wide radius without permitting any of them to shine upward into an aviator's eyes.

Floodlights have many uses besides those connected with aviation. Fire departments use them, as well as searchlights, to light up the scene of a night fire and make the work of fighting it easier. Many wrecking trains are also equipped with floodlights for use when wreckage must be removed from the tracks at night.

The soft, even glow which lights up the outer walls of some buildings comes from concealed floodlights. Floodlights are also now used to illuminate playing-fields for night games of baseball, football and other sports. Have you ever seen a game of baseball or football at night, when floodlights made it possible to see the players as well as by broad daylight?



Brown Brothers.

CONSTRUCTION OF A MODERN OIL BURNING FURNACE

This is the latest type, in which the furnace and burner are built together as a unit. The "gun" in this burner shoots downward, not horizontally, as the older "gun-type" burners do.

Oil Burners.—For several generations, coal has been practically the only fuel burned in furnaces. Within the last ten years or so, however, the use of fuel oil for heating plants has become practical, and its use is increasing rapidly.

Fuel oil, often called furnace oil, is one of the products of petroleum. It requires a special type of burner in which the oil

is vaporized (turned into a vapor), mixed with air, and sprayed into the fire box, where it is ignited. The various kinds of oil burners accomplish these four steps by different methods. In the "gun-type" burner the oil is forced through a nozzle that breaks it up into fine mist. A stream of air is mixed with this oil mist. The air helps to vaporize the oil and also adds the correct amount of oxygen necessary for complete combustion of the oil vapor. The mixture is ignited by either an electric spark or by a pilot gas light.

In the "rotary-atomizer type" of burner the oil is whirled out by centrifugal force[1] in fine drops from slots in a rapidly turning plate in the center of the firebox. This plate is driven by an electric motor. As the oil drops leave the plate they are mixed with a stream of air, which helps vaporize them. In still another type of burner, the oil is vaporized by heat. The gun type of burner is gradually replacing all other types. Oil burners do away with shoveling coal and ashes and are much cleaner than coal-burning furnaces.

Heating by Gas.—Gas is sometimes used as a fuel in the furnace, especially in regions where natural gas is available. In steam and hot-water furnaces the gas flames heat the water in the boiler. In hot-air furnaces a heavy plate made of material that retains heat a long time is heated by the gas flames. Some of the advantages of the gas furnace are that it does not require expensive apparatus and it never needs refueling of storage tanks or bins.

Heating by Electricity.—Since the application of the resistance coil[2] to practical purposes, dozens of useful devices, such as electric toasters, percolators, and heaters, have increased our comfort and convenience. The electric furnace is one of the more recent devices which make use of the resistance coil. Its heating unit consists merely of numerous powerful resistance coils.

The essential feature of the electric furnace is a storage tank made like a huge thermos bottle. Water is heated by the electric

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[1] See definition on page 619.
[2] See description on page 231.

heating unit. In places where the night rate for electricity is cheaper, the heating is usually done at night. The current is shut off during the day, and the hot water stored in the tank at night is automatically released to the radiators as needed.

Electricity would be the ideal heating agent for home furnaces if it were not so expensive. Wherever electric furnaces have been put into operation they have proved very satisfactory. They are perfectly clean, need no attention, are free from the danger of fire, and require no chimney. Whether or not the electric furnace will be the furnace of the future depends on our ability to generate electricity on a larger scale and at a much cheaper rate than at present.

The Thermostat.—One of the most useful accomplishments of modern mechanics and engineering is automatic control. More and more labor-saving and safety devices for automatically controlling machinery are appearing each year. The *thermostat,* a device for regulating the temperature of buildings automatically, has made a great advance in efficient heating.

In a home, the thermostat is usually placed on a wall in one of the rooms on the first floor. It consists essentially of a metal rod or coil that is sensitive to temperature changes, expanding as the temperature of the room becomes higher and contracting as it becomes lower. Sometimes two rods of different metals are fastened side by side. As one expands more slowly than the other, the rods are curved to a greater or less extent with each change of temperature. A dial on the instrument is set at the desired temperature. When the temperature increases, the sensitive rod or coil expands, and when it reaches the point at which the thermostat is set (usually 68° to 70° F.) an electrical contact is made which sets up an electric current. This current operates controls which either close the drafts (in the coal furnace) or cut down the amount of fuel (in the oil burner and the gas furnace). The electric furnace is also regulated by thermostat. In some types of oil-heated hot-water furnaces which are used also to supply running hot water, the thermostat regulates the heat of the rooms by shutting off the hot water from the radiators.

When the temperature of the room falls below the point at

which the thermostat is set, the current is again turned on, which starts the controls that increase the amount of heat in the furnace. Some thermostats have a clock, by which the heat may automatically be turned off or on, or by which the temperature may be changed, at any time required.

Dry Ice.—If you live in or near a large city, you may have had delivered to you a package of ice cream that was so hard that you could not cut it. On investigating you found in the ice-cream package a small compact disk of flaky white material that looked like compressed snow. This material was *dry ice.*

Dry ice is formed by placing carbon dioxide under great pressure and drawing off the heat that is generated by the pressure. In the process, the gas becomes a white, flaky solid with a temperature of about 109 degrees below zero. Dry ice gets its name from the fact that it passes directly back into its gaseous form instead of turning to a liquid as ordinary ice does. Dry ice has several advantages over water ice. It never wets the food, and requires no drainage pipes. One pound of dry ice is as effective as fifteen or twenty pounds of water ice. For this reason dry ice is coming into wide use for keeping materials cold during transportation as it requires much less space than does water ice. The space thus saved can be used to store more goods. When dry ice is properly covered it evaporates very slowly. Meats and other perishable goods, in freight cars and trucks, may thus be kept cold with dry ice for several days without renewing the supply, making long distance shipments possible. Dry ice is also used in ice cream stores, meat markets, and other places where perishable foods are kept.

Air Conditioning.—The country of Siam lies in southern Asia, not far from the Equator. It is a hot country, with a moist, unpleasant climate. Yet there is one place in Siam where people are always comfortable—in the palace of Siam's king and queen. No matter how hot and steamy the air may be outside, the air inside the palace is always cool and pleasant. *Air conditioning* is the magic that makes this possible.

The term air conditioning, or "indoor weather" as it is sometimes called, has come into use only within the last few years. It

means, essentially, supplying clean air that has exactly the right temperature and moisture content for human comfort and health. With modern equipment, it is possible now to do this in both winter and summer. To maintain the proper temperature, a heating unit must be used in winter, and a cooling unit in summer. To maintain the proper moisture content, moisture must be added to the atmosphere in winter and reduced in summer. The reason for this is that in winter there is not enough moisture in the air for health, and in summer there is usually too much for our comfort.

In both summer and winter the air is first "washed," or filtered, to free it of dust, soot, smoke, and bacteria. This is done by forcing it through fine sprays of water, through closely woven moist cloth, or through fibrous material. Radiators are not used in air conditioning. The conditioned air is gently circulated throughout the room or building by means of a system of large pipes similar to those used in the hot-air heating system.

Air Conditioning in Theaters.—Most large theaters today are air-conditioned in both summer and winter. In winter the air, after being washed or filtered, is passed over steam coils to be heated. Then it is humidified, or given the right amount of moisture, by being passed through finely sprayed water or through steam jets. The air is now "conditioned" and ready to be circulated. Powerful blowers force it upward through pipes and out into the auditorium through numerous small openings in the ceiling. It flows gently downward through the auditorium and passes out through openings under the seats. This air, after being mixed with a new supply of conditioned fresh air, and reheated if necessary, is then recirculated.

In summer the same system is used, except that the air, after being washed, is sent through a cooler and dehumidifier, or device for reducing the amount of moisture in the air. The cooler is made on the same principle as that of the home electric refrigerator.[1] In passing through the cooler, some of the moisture in the air is condensed and forms water, as cool air cannot hold so much water vapor as warm air. This water is drawn off. The air is now

[1] See description on page 62.

clean, cool, and dry. If too cool, it is slightly reheated, or a little warm air is added to it to bring it to the required temperature. A temperature of twelve to fifteen degrees lower than that of the street has been found to be more comfortable than a fixed temperature, which might be on some days thirty degrees cooler than the air outside. The conditioned air is then circulated through the auditorium. An engineer is usually in charge of the air-conditioning system to watch the temperature and the humidity and to make the necessary adjustments when weather conditions change.

Air Conditioning in Schools.—Probably it has never occurred to you that the air in your classroom may have an important effect on your ability to do good work. Tests made in schools, however, have definitely proved that when the air is too warm students have difficulty in concentrating on their studies. They are dull and sleepy. Likewise, when the air is too cold the students are uncomfortable and cannot concentrate well. A temperature of from 68° to 70° has been found to be most satisfactory, especially when the air is not too moist or too dry, and is kept circulating.

The condition of the air may also have important effects on health. If a number of students sit for hours in a stuffy room, breathing and re-breathing the same air, there is a good opportunity for the germs of colds and other diseases to develop and spread. Hence proper ventilation is extremely important in school buildings.

Few school buildings are yet equipped with air conditioning apparatus, but as time goes on it seems likely that more and more will be air conditioned. It will be a real step in advance in preventing the spread of disease and in increasing efficiency when classrooms are provided with fresh, clean air at the proper temperature and with just the right amount of moisture.

Air Conditioning in the Home.—Air conditioning in the home, while practicable, has not yet come into general use, chiefly because of the expense involved. It is believed by forward-looking persons, however, that the manufacture of effective home air conditioning apparatus within the reach of the average pocketbook will be one of the next great advances in human comfort.

Home air conditioning is carried out on the same general principle as that used in theaters. The winter air-conditioning apparatus is usually contained in a single compact cabinet. It consists of a washer or filter, a coil of steam pipes for heating, and a device for humidifying. The temperature of the air is controlled by a thermostat, and the amount of moisture is regulated by a humidistat. Thus any desired temperature or humidity may be maintained automatically. The heating unit is attached to pipes which lead to all rooms of the house, and the conditioned air is forced through these pipes by a fan or blower. The air is drawn back to the heater from openings in the rooms, thus providing a gentle and continuous circulation of warm, conditioned air throughout the house. The summer air conditioner is also contained in one unit, which includes the washer, cooler, and dehumidifier. When new houses are to be air-conditioned, the spaces between the outer and inner walls are often filled with an insulating material. This insures a more even temperature and cuts down the cost of operating the air-conditioning apparatus.

For those who cannot afford to air condition their entire house during the summer, small portable units, suitable for the air-conditioning of one room, have been developed. These have no pipes, the air of the room passing into them at the bottom and coming out at the top properly conditioned. One of these units may be placed in the living room and another in a warm or stuffy bedroom. Or only one may be used, and transferred from one room to another as needed. There are various devices for increasing the humidity during the winter months in houses that are not otherwise air conditioned.

Other Uses of Air Conditioning.—Air conditioning has been found to increase both the efficiency and comfort of workers to such an extent that many offices are now being equipped with it. Stores and restaurants find that air conditioning increases their business, especially in the summer. In most of these places the small individual unit is used and either placed on the floor or fastened to the wall. Some of these units are year-round air conditioners, but most of those used are summer air conditioners only.

On some railroads, tne passenger cars on through trains are air-conditioned. Thus the discomfort of summer travel by train is largely eliminated and winter travel is also improved.

It is believed that air conditioning, together with improvements in health conditions brought about by proper sanitation and the control of disease-bearing insects, will eventually open up the tropics to a much greater development by white men than has heretofore been possible. Large electric companies of this country have sent investigators to the tropics to make a survey of these possibilities.

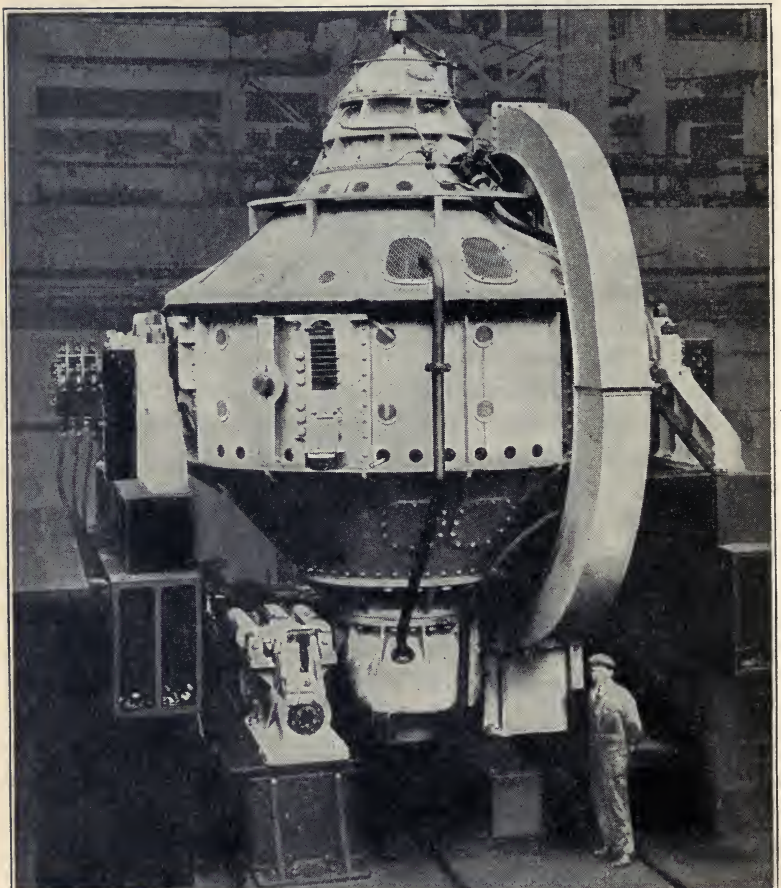
The Gyroscope.—A scientist with a sense of humor once packed his suitcase to go on a trip. In it he put a strange device consisting of a heavy metal wheel mounted in a metal framework. When he reached the station he opened the suitcase, set the wheel spinning rapidly, then closed the suitcase again and called a porter. The porter picked up the suitcase and started to carry it to the train. All went well until he tried to turn a corner, when the suitcase began to act very strangely. No matter how hard he pulled and tugged, the porter simply could not make that suitcase turn the corner. It resisted all his efforts until at last the scientist came up and stopped the wheel. The porter thought the suitcase was bewitched, but the scientist knew that its strange actions were due to the spinning wheel, or *gyroscope,* which he had placed inside.

Have you ever had a toy gyroscope? If you have, you can easily see why this strangely-acting device has contributed so much to the advancement of mechanics in the last few years. The gyroscope is essentially a heavy wheel, mounted in a metal frame. When this wheel is revolving rapidly, its inertia[1] tends to make it remain in the same position. A spinning top has this same characteristic. In fact, a top is in effect an unmounted gyroscope. When a top is spinning rapidly, it is difficult to knock it over. If you try to push it over, it merely moves along in the same upright position. Even if you knock it from the table to the floor, it continues to spin in the same position it had while on the table. It is the same way with the gyroscope, except that the gyro-

[1] See description on page 15.

scope is always mounted. Any force applied to a gyroscope in an attempt to change its position is met with great resistance. These two features of a gyroscope—its tendency to keep its position and its resistance to a force—are utilized in many useful ways.

Gyro-stabilizers.—If you have ever been seasick, or have



Sperry Gyroscope Company.

A GYRO-STABILIZER

This huge stabilizer, weighing 220 tons, was installed, with two others just like it, on the Italian liner *Conte di Savoia*. When the ship starts to roll, the big gyroscope wheel within each of the stabilizers counteracts the rolling movement and keeps the ship on a fairly even keel.

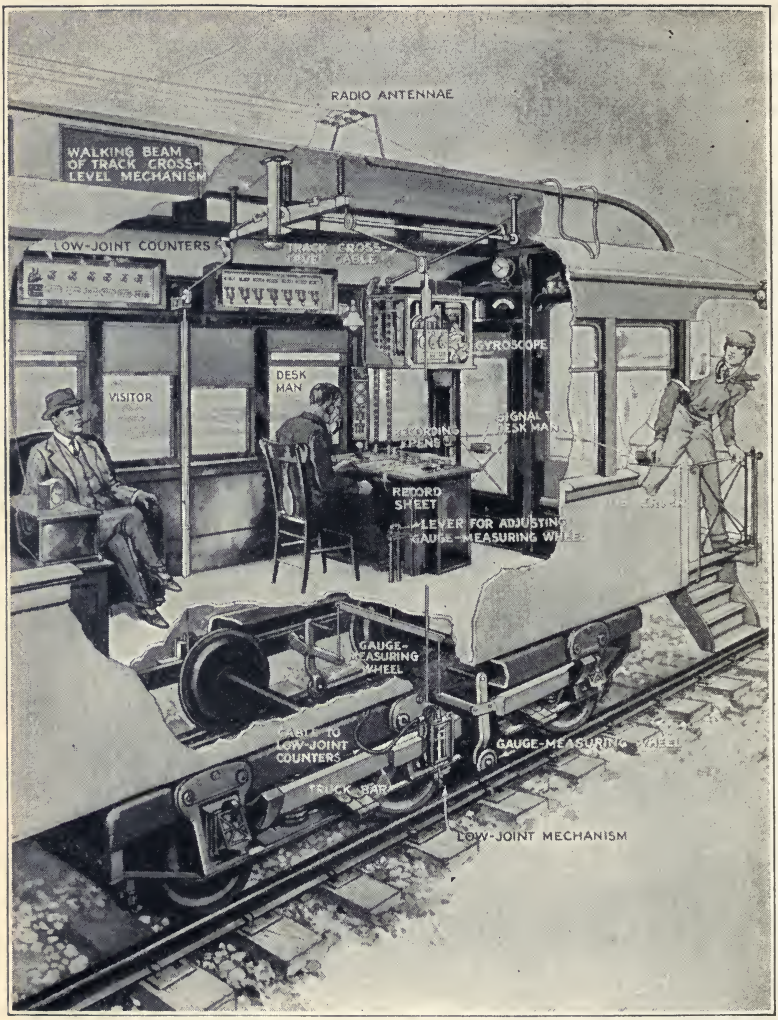
tried to eat breakfast on an ocean liner when the ship is rolling heavily, you can appreciate what a comfort it would be to have this rolling overcome. Here is where the gyroscope is of great assistance. One or more huge gyroscopes, called gyro-stabilizers, are firmly fastened in the center of the ship. The huge wheels of the gyro-stabilizers are turned by electric motors. Because of its tendency to remain spinning in the same position, and because it takes such a great force to change that position, each gyro-stabilizer resists the attempts of the waves to roll the ship. The stabilizers cannot prevent the rolling entirely, but they will not allow the ship to roll beyond a certain point. Very few ships are at present equipped with gyro-stabilizers, but these instruments have proved successful where used.

Gyro-stabilizers are also used in airplanes. There are two types of airplane stabilizers. In one type the stabilizer works much the same as that on a ship. In the other type, the gyroscope operates by relays a system of levers that move the little hinged surfaces on the rear of the wings that are used to keep the ship on an even keel. The airplane is thus automatically balanced through the action of the gyroscope.

Torpedoes used in naval warfare are equipped with gyro-stabilizers. The stabilizer is set in motion by compressed air just before the torpedo leaves the tube. Torpedoes travel at the speed of an express train, about eight or ten feet below the surface of the water. The gyro-stabilizer helps the torpedo to maintain its level, keeps the course true, and brings the torpedo back to its original direction if anything should turn it aside. The gyroscope continues to spin for about fifteen minutes, which is about as long as a torpedo can travel.

The Gyro-Compass.—The magnetic compass, as we have learned, is affected by any steel that is near it. When ships, especially battleships, began using larger and larger quantities of steel, it was found that all this steel was interfering with the proper working of the compasses on these ships. This led to the invention of the gyro-compass.

The gyro-compass is essentially a gyroscope, in which the wheel is turned rapidly by an electric motor. A dial attached to



Sperry Gyroscope Company.

A GYRO AUTOMATIC TRACK-RECORDER CAR

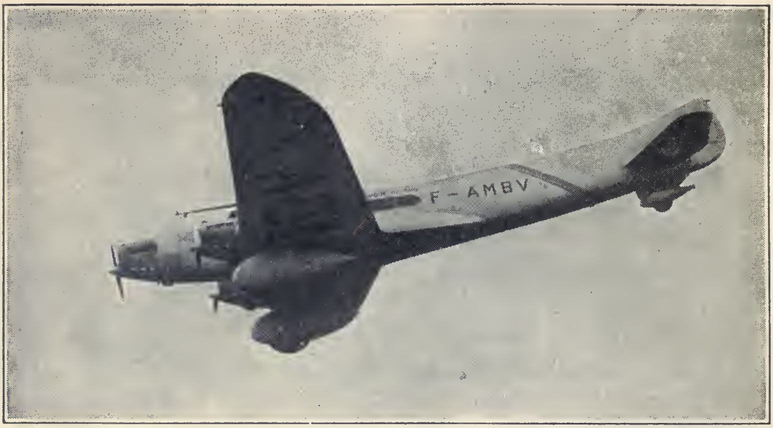
This diagram shows how the apparatus of the track recorder is installed on the special track-recorder car. Note the gyroscope. The gauge-measuring wheel registers rail spread. See if you can find out how this mechanism detects differences in rail level.

the frame of the gyroscope indicates the points of the compass. This dial differs from the magnetic compass in having no needle. Instead, the whole dial, by remaining always in the same position, regardless of which direction the ship turns, indicates the different points of the compass.

Other Uses of the Gyroscope.—Many other uses of the gyroscope have been developed. In both ships and airplanes, gyroscopes are used in automatic control instruments called "automatic pilots." On ships the *gyro-pilot* is sometimes used. This device is connected with the gyro-compass, which sets up an electrical connection with the steering apparatus whenever the ship starts to move from the course set. Thus this tireless mechanical pilot works day and night without rest and with far greater accuracy than any human helmsman. In the airplane, the automatic pilot works similarly. The gyroscope makes electrical connections which operate the airplane's controls.

One of the most interesting applications of the gyroscope is the automatic railroad track recorder, which consists of a gyroscope and a complicated system of machinery that registers any tendency to change the position of the gyroscope. This ingenious device thus detects the slightest inequalities of the track as the train in which it is carried passes over the rails. Any difference of elevation of the two rails, any undue depression, or any rail spread is not only detected, but automatically recorded on a chart. The automatic track recorder, when placed on a train and run over a stretch of track, does the work of many track-walkers in far less time. The figures it records are used as a basis for future track repairing.

Streamlining.—Ever since men first began to build boats, they have been faced with the problem of cutting down the resistance of the water so that the boats would move forward more quickly and easily. For thousands of years it was believed that a long, slim shape, sharp at the front, gave the best speed. Until recent years, therefore, the fastest boats have been built with long, sharp bows. Since air offers resistance much like that of water, racing automobiles and dirigible balloons were also built with pointed fronts.

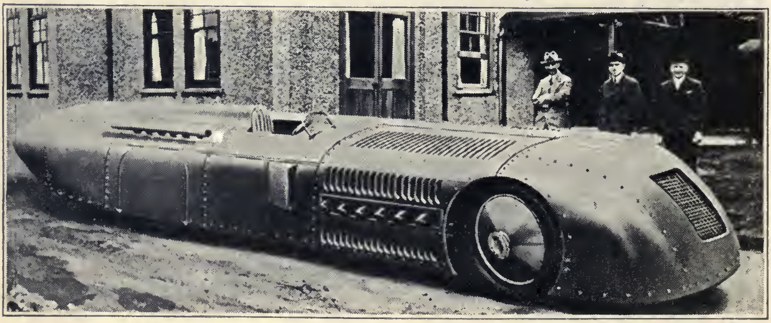


Keystone View Company.

A STREAMLINED AIRPLANE

This French monoplane flew from Paris to South America and back. Notice the raindrop-shaped guards over the wheels to cut down air resistance.

Following the invention of the airplane, men began to pay more attention to the question of air resistance. Wind tunnels were built—large tubes through which a powerful blast of air could be forced by a motor-driven propeller. In the wind tunnels, tests were carried out to see what shape an airplane should have in order to offer the least resistance to the air. It was discovered that a raindrop shape, with a rounded front and a tapering rear,



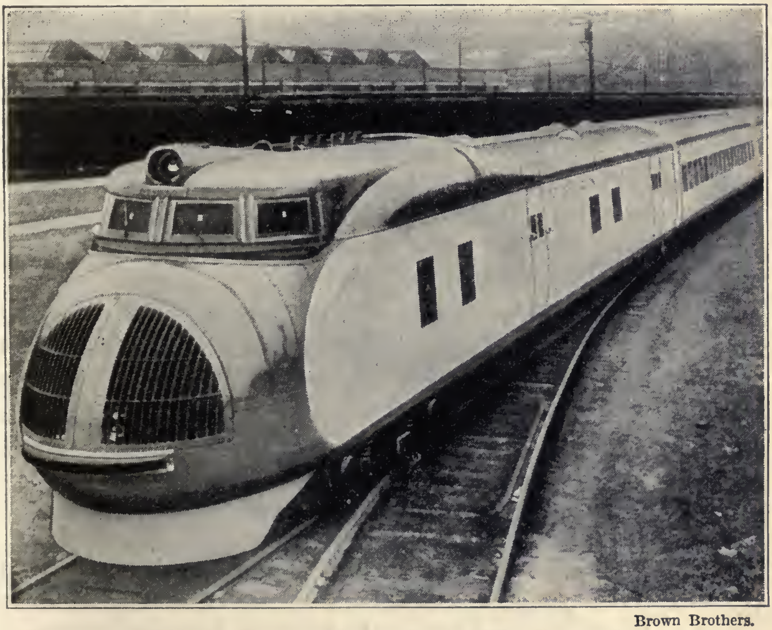
Brown Brothers.

A STREAMLINED RACING CAR

This automobile is designed to travel more than two hundred miles an hour. Notice the rounded front and tapering rear, which greatly reduce air resistance.

gave the best results. The air flows around a body of this shape with very little disturbance, whereas the air forced aside by a sharp cutting front forms a partial vacuum which tends to hold back the moving body. A blunt, or chopped-off, rear also causes such a retarding vacuum.

A body designed to pass through the air or water with only a small amount of resistance is said to be *streamlined*. Today, all



Brown Brothers.

A Streamlined Train

This fast new train can travel over one hundred miles an hour. Notice the rounded front, which slips through the air with a minimum of resistance.

airplanes are more or less streamlined, and racing planes are very carefully shaped to cut air resistance to a minimum. Racing cars are also designed to travel at high speeds without creating a vacuum to hold them back. Some automobile manufacturers are now turning out streamlined closed cars for general use, and fast streamlined trains are appearing on some railroads. Even the new

ocean liners are being made more efficient. The *Europa* and *Bremen,* with rounded bows and tapering sterns below the water line, are faster and more economical to run than the older ocean liners with their sharp, cutting bows and blunt sterns.

SUMMARY

The autogiro is supported in the air by a horizontal wheel, or windmill, instead of by wings. It is safer than the airplane and can take off and land within a smaller area.

Infra-red rays are not visible to the eye, but will affect photographic negatives. They are used in taking pictures of distant objects, and also in taking photographs in foggy weather and at night.

A photoelectric cell is a special glass bulb, useful in varying the strength of an electric current to correspond to variations in the intensity of a beam of light.

Talking motion pictures are of two kinds. In one type of talking picture, the actors' voices are registered on phonograph records. In the other type, both the sounds and the pictures are recorded on the same strip of film.

Telephotography is the sending of pictures by telegraph or radio.

Television, the latest development in radio, permits the listener to see the broadcaster as well as hear him.

One may now telephone to countries in Europe by means of a combination telephone and radio system, which uses short radio waves to bridge the gaps where there are no telephone wires.

Radio is used in many ways to make flying safer. One of the most important of these ways is the use of radio beacons, which guide planes to them by means of continuous radio signals.

One of the many uses of searchlights and floodlights is to make night flying and landing safe.

The oil burner uses fuel oil, which is vaporized, mixed with air, and sprayed by force into the firebox of the furnace, where it is burned.

Gas is used as fuel in some heating systems.

The electric furnace uses resistance coils to heat water, which is stored in a tank like a huge thermos bottle and released to the radiators as needed.

A thermostat is an automatic device for regulating the temperature of a room or building.

Dry ice, made by compressing and cooling carbon dioxide gas, is more effective than water ice, and is taking its place for many cooling purposes, especially in the shipment of perishable foods or foods that must be kept very cold, such as ice cream.

Air conditioning means supplying clean air that has exactly the right temperature and humidity for human comfort. Successful air-conditioning apparatus is now in use in theaters, homes, offices, stores, restaurants, and trains.

The gyroscope is a heavy wheel that tends to hold the same position in which it started, and to resist any force applied to change that position.

The gyroscope is used in stabilizers for keeping ships and airplanes on an even keel; in the construction of the gyro-compass, which is more reliable on modern ships than the magnetic compass; in automatic pilots which steer ships and airplanes automatically; and in automatic track recorders, which detect and record inequalities in railroad tracks.

A body designed to pass through the air or water with only a small amount of resistance is said to be streamlined. Today many airplanes, automobiles, trains, and steamships are streamlined.

Fact and Thought Questions

1. What is the essential difference between an autogiro and an airplane? In what ways is the autogiro an improvement over the airplane?
2. What are infra-red rays? Give some of their uses.
3. Describe the photoelectric cell and tell how it works.
4. Name several uses of the photoelectric cell.
5. Tell how the simpler form of talking motion pictures operates.
6. How are sounds recorded on the sound strip of a talking motion picture film? How are they reproduced?
7. What is telephotography? How is it done?
8. How is the image of a person broadcast by a television sending set?
9. Tell how a television receiving set works.

10. Name several subjects which you would like to see broadcast by means of television.
11. How could you telephone across the ocean?
12. Why do you suppose it is more expensive to telephone from New York to London than from New York to San Francisco, which is even farther away?
13. How does radio help make air travel safer?
14. Describe a situation in which an air liner might be saved by a radio beacon from destruction.
15. What is the difference between a searchlight and a floodlight? Name some uses of each.
16. Describe the four steps in converting fuel oil to flame in an oil burner.
17. How is gas used in heating?
18. Tell how an electric furnace operates.
19. Complete the following statements orally:
    (a) A thermostat is a device to regulate the..................
    (b) A humidistat is a device to regulate the ....
20. How is dry ice made? Why is it more efficient than water ice? What special uses has it?
21. What is meant by air conditioning?
22. Describe the system of air conditioning in a theater.
23. What is the advantage of washing, or filtering, the air that we breathe?
24. Describe a gyroscope. What remarkable qualities has it?
25. Name some of the uses of the gyroscope.
26. Can you think of any other way in which the gyroscope may be put to practical use? If so, describe it.
27. The steamship *Mauretania* has a long sharp bow and the *Europa* has a rounded bow. Which boat do you think is faster? Why?

Projects

1. Bring to class a piece of moving-picture film, including a sound strip. Explain its use.
2. Bring to class a picture which has been sent by telephotography. Examine it closely and explain its appearance.
3. Write a composition or plan a talk on what important effects air conditioning may have in the future.
4. Obtain a toy gyroscope and experiment with it.
5. Carve a model of a streamlined airplane or racing car. Explain to the class the advantages of its shape.

Outdoor Observation

1. Watch for the next autogiro that passes over your town, and, if possible, study the motion of the horizontal blades.

2. Visit an airport and notice the various devices used to guide airplanes to the landing field and to make it safe for them to land.
3. Observe various ways in which air resistance is reduced in different makes of automobiles.

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GENERAL THOUGHT QUESTIONS FOR DISCUSSION AND REVIEW

GROUP VI

1. Is it true or false that the main purpose of the stems of plants is to store up surplus food?
2. What is osmosis? Is it different in its action in plants and in animals?
3. Is it true or false that earthworms are pests and should be destroyed?
4. Does sound travel fastest in air, in water, or in steel?
5. In which of the following are vitamins found: salt meat, fish, raw vegetables, canned goods, cookies, fresh fruits?
6. If a physician told you that you needed a protein diet, name several foods you might eat.
7. Name several distinctly different examples of oxidation.
8. Why are double windows helpful in keeping a house warm in winter?
9. Is it true or false that the melting point of ice is the freezing point of water?
10. What makes a flame bright?
11. Would you expect to be warm or cool if the temperature measured 64° Centigrade?
12. Explain how the surface of an electric flatiron becomes hot.
13. Is it true or false that the electricity which produces lightning is of the same nature as that which produces electric light in our homes?
14. Give a common example of changing electrical energy to chemical energy. Explain.
15. Name four modern inventions now in general use. Name the inventor of each.
16. How does sap travel from the roots to the tops of trees?
17. With the help of labeled diagrams on paper or on the blackboard, show how to demonstrate the digestion of starch. Tell what was used, what was done, what happened to the starch and how you proved that starch was changed.
18. Why can you grip an object more firmly with a pair of pliers than with your fingers?
19. If Edison's main inventions suddenly were lost to us, how would our daily lives be affected?
20. Name several discoveries and inventions which have been of marked help to farmers.
21. Is it true or false that seeds should be kept in a warm, moist place until needed for planting?

22. Does matured seed suffer from exposure to freezing temperature? Explain.
23. Why are many dead young trees found in any dense natural forest?
24. Name several ways in which we would be seriously affected by a shortage of lumber supplies. Name several instances of the substitution of other materials for wood in the making of articles we use.
25. Name the plants that had a part in providing your last night's dinner.
26. What harm do weeds do in the vegetable garden?
27. Name several plants that had a part in furnishing your home.
28. (a) How would you prove that bacteria are found in food and water?
    (b) Mention three ways in which bacteria are useful to us and two ways in which they are harmful to us.
    (c) State one thing that Jenner, Lister or Pasteur did to aid us in the control of bacteria.
29. Are all foods preserved in the same way? Explain.
30. (a) Describe (indicating four steps) an experiment to prove that a solid or a liquid occupies more space when heated than when cold.
    (b) Make two labeled drawings to illustrate your description.
31. To which special science should we look for a full understanding of the principles governing: plant growth; the movements of the planets; the working of an electric washing machine; the changes that occur in cooking food; the circulation of the blood?
32. What advantages has a dirigible over an ordinary balloon?
33. (a) Describe fully how you would set up and use apparatus to show how soil water gets into the roots of plants.
    (b) To make your description clear, use at least two fully labeled drawings showing different stages of the process.
    (c) What must soil water contain in order to be of the greatest use to plants?
34. (a) Name two substances required that burning may occur, whether rapidly in a burning candle or more slowly in a living human being. Explain why each substance is necessary.
    (b) What two substances are given off by both a burning candle and a living human body?
    (c) Of what process going on in the candle and in the human body are these substances a result? Explain fully.
    (d) How may it be proved that one of these substances is given off by the candle and by the human body?
35. Name several plants used as foods by both man and animals.
36. Leave a blanket out on the lawn for two or three days and the grass under it begins to turn yellow. Why?
37. Describe one recent invention which has had an effect on your life.
38. Which general topic in this book has interested you most? Why?

PRONOUNCING GLOSSARY

TO THE STUDENT.—This glossary is a collection of explanations and simple definitions of words and terms as used in this book, as well as the pronunciations of those which might present difficulties. The meaning of each term has been made clear in the text at the time of its first use. It is important, however, that the meanings and uses of these terms become a permanent part of your vocabulary. Cultivate the habit of referring to the glossary.

The glossary affords an interesting means of review. Start anywhere in the list of terms and see how many you can define in your own words. Compare your definitions with those given here. Take a group of terms and classify them according to the general subjects to which they refer. Select terms and see if you can give examples or illustrations. In such ways the use of this glossary will fix in your mind the special vocabulary of General Science.

KEY TO PRONUNCIATION

ā as in āle, māker
ă as in ăm, hăt
ă as in fin*ă*l, *ă*ccount
â as in pârent, câre
ä as in ärm, fäther
ȧ as in ȧsk, stȧff
ȧ as in sof*ȧ*, ide*ȧ*
ȃ as in savȃge, senȃte
ē as in ēve, concrēte
ĕ as in ĕnd, pĕt
ĕ as in rec*ĕ*nt, nov*ĕ*l
ê as in sociêty, êvent
ẽ as in evẽr, readẽr
ī as in īce, chīld
ĭ as in pĭt, ĭll
ō as in ōld, nōte
ŏ as in nŏt, hŏt
ŏ as in c*ŏ*ntented
ô as in lôrd, ôrder
ȏ as in ȏbey, tȏbacco
ö as in coöperate
oi as in oil, boil
o͞o as in mo͞on, bo͞ot
o͝o as in bo͝ok, lo͝ok
ou as in out, house
ū as in ūse, cūbe
ŭ as in ŭp, tŭb
ŭ as in circ*ŭ*s
û as in bûrn, hûrl
ȗ as in ȗnite
zh as the **z** in seizure

A

Abdomen (ăb-dō′mĕn): The lower body cavity containing the stomach and intestines.
Abnormal (ăb-nôr′m*ă*l): Different from the type; irregular.
Absorption (ăb-sôrp′sh*ŭ*n): The taking up of matter or energy by any substance. The taking up of fluids through membranes by living cells.
Accommodation: The adjustment of the lens of the eye to suit different distances; brought about by a change in the curvature of the surfaces of the lens.
Acetylene (*ȧ*-sĕt′ĭ-lēn): A colorless gas used for lighting.
Acid: A substance which has a sour taste. The test for an acid is that it turns blue litmus paper red.
Adaptation: The way in which a living thing, or any of its parts, is fitted to its use or surroundings.

Adenoids (ăd′ē-noidz): Spongy enlargements of the tissues of the upper end of the pharynx which cause difficulty in breathing through the nose.

Adrenal glands (ăd-rē′năl): Two ductless glands, one in front of each kidney.

Adulterant (ȧ-dŭl′tẽr-ănt): A substance placed in food to increase its bulk or cheapen it, which makes it less nutritious.

Aëration (ā-ẽr-ā′shŭn): The process of introducing air into a substance, such as soil or water.

Aërial (ā-ē′rĭ-ăl): One or more wires suspended in the air to give out or collect radio waves; antenna.

Agar-agar (ä′gär-ä′gär): A jelly-like substance obtained from seaweed; used as a food for the growth of bacteria.

Agriculture: The cultivation of the soil, including raising of crops.

Air: A colorless, odorless, tasteless mixture of several gases; necessary to the respiration of all living things.

Air conditioning: Supplying clean indoor air that has exactly the right temperature and moisture content for human comfort and health.

Airplane: A heavier-than-air machine capable of flying in the air.

Air pump: A pump for exhausting air from a closed space, or for forcing air into a closed space.

Air sac: An air cell in a living thing.

Airship: See dirigible balloon.

Albumen (ăl-bū′mĕn): The white of egg; a form of protein.

Albumin (ăl-bū′mĭn): A thick, sticky nitrogenous protein found in both animal and plant tissue. An essential part of the blood.

Alcohol: The intoxicating part of liquors. Commonly produced by the fermenting action of yeast on sugar.

Alimentary canal (ăl-ĭ-mĕn′tȧ-rĭ): The whole digestive tract of a man or an animal.

Alkali (ăl′kȧ-lī): One of a class of substances which is soluble in water or alcohol, and which, when combined with fats or oils, makes soap. An alkali turns red litmus paper blue. Soda and potash are two of the most common alkalis.

Alloy (ă-loi′): A substance composed of two or more metals closely united, usually by being fused, or melted together, such as solder or brass.

Alternating current: An electric current that changes its direction in a circuit many times per second.

Altimeter (ăl-tĭm′ē-tẽr): An instrument much like the barometer, used for measuring height above sea level.

Altitude: Height; distance above sea level.

Ammeter (ăm′mē-tẽr): An instrument for measuring, in amperes, the amount of an electric current.

Ammonia (ă-mō′nĭ-ȧ): A colorless, pungent, alkaline gas, composed of hydrogen and nitrogen. Used in making artificial ice, in solutions as a medicine, and as a general household cleansing agent.

Amoeba (ȧ-mē′bȧ): A minute, one-celled animal of constantly changing shape.

Ampere (ăm-pâr′): A unit used for measuring the amount of an electric current.

Amylopsin (ăm-ĭ-lŏp′sĭn): A ferment in pancreatic juice which helps digest starch.

Anaesthetic (ăn-ĕs-thĕt′ĭk): A gas or a drug used to reduce pain or to produce unconsciousness. Cocaine and ether are examples.

Anemometer (ăn-ē-mŏm′ē-tẽr): An instrument for determining the force or velocity of the wind; a wind gauge.
Aneroid barometer (ăn′ẽr-oid bȧ-rŏm′ē-tẽr): A barometer whose action depends on the changing pressure of the atmosphere upon the flexible top of a metal box from which the air has been largely exhausted.
Animal: Any living creature, such as a mammal, a fish, a bird, or an insect.
Annealing (ȧ-nēl′ĭng): The process of heating and then cooling a substance, such as glass, to make it less brittle.
Antenna (ăn-tĕn′ȧ): See aerial.
Anthracite coal (ăn′thrȧ-sīt): A hard, natural coal having high luster.
Anticyclone (ăn′tĭ-sī-klōn): A movement of air spirally outward from a center of high pressure.
Antipyrin (ăn-tĭ-pī′rĭn): A narcotic drug made from coal tar.
Antiseptic (ăn-tĭ-sĕp′tĭk): A substance which checks the growth of disease germs.
Antitoxin (ăn-tĭ-tŏk′sĭn): A serum injected into the blood to prevent or cure a disease.
Anti-trade winds: Masses of air flowing north and south from the belt of equatorial calms, above the trade winds.
Aorta (ā-ôr′tȧ): The large artery that carries the blood from the left ventricle of the heart for distribution to all parts of the body except the lungs.
Apoplexy (ăp′ō-plĕk-sĭ): Loss of consciousness caused by a blood clot on the brain. It is frequently fatal.
Apparatus (ăp-ȧ-rā′tŭs): A device for performing a special work.
Aquarium (ȧ-kwā′rĭ-ŭm): A water-filled globe or tank, or a building, in which water animals and plants are kept.
Aqueduct (ăk′wē-dŭkt): A man-made channel for conveying water.
Arc light: An electric lamp in which an electric current, by jumping a slight gap between the ends of two carbon rods, produces intense heat and a brilliant light.
Armature (är′mȧ-tūr): A soft iron bar placed across the poles of a horseshoe magnet to preserve its magnetic strength; the iron bar in a telegraph sounder or electric bell which, when attracted by the magnet, causes sounds; a rotating iron core wound with insulated wire, an essential part of a dynamo or electric motor.
Arteries (är′tẽr-ĭz): Tubes which distribute the blood from the heart.
Artesian well (är-tē′zhăn): A well from which water flows or spouts naturally.
Artificial: The opposite of natural; produced by human labor.
Aseptic (ȧ-sĕp′tĭk): Free from harmful germs.
Asphalt: A natural, tar-like, pitchy substance, easily worked when heated. When rolled firm it forms an excellent road surface.
Asphyxia (ăs-fĭk′sĭ-ȧ): Apparent death produced by suffocation.
Aspirin: A narcotic drug made from coal tar.
Assimilation (ă-sĭm-ĭ-lā′shŭn): The changing of digested food into living tissue.
Astigmatism (ȧ-stĭg′mȧ-tĭz′m): A defect of the eye due to irregularity in the curvature of the cornea or of the lens.
Astrolabe (ăs′trō-lāb): An instrument formerly used in navigation for determining latitude.
Astronomy (ăs-trŏn′ō-mĭ): The science which treats of the heavenly bodies.
Atmosphere: The mass of air surrounding the earth.

Atom: The smallest unit of matter into which an element can be divided and retain its identity.
Atomic theory (*ȧ*-tŏm′ĭk) **:** The theory that all matter is composed of atoms.
Attraction: A power in a body by which it draws things to itself.
Auditory canal (ô′dĭ-tô-rĭ) **:** The passage extending inward from the outer ear to the tympanic membrane, or ear drum.
Auditory nerve: The nerve which carries sound impulses from the cochlea, in the inner ear, to the brain.
Auricle (ô′rĭ-k′l) **:** One of the two upper chambers of the heart.
Autogiro (ô-tō-jī′rô) **:** A heavier-than-air machine, capable of flying in air, and supported by a horizontal wheel, or "windmill."

B

Bacilli (b*ȧ*-sĭl′ī) **:** Rod-shaped bacteria, such as tuberculosis germs.
Bacteria (băk-tē′rĭ-*ȧ*) **:** The plural of bacterium. The smallest form of plant life; consists of a single cell.
Bacteriology (băk-tē-rĭ-ŏl′ô-jĭ) **:** The science which treats of bacteria.
Balanced aquarium: An aquarium in which the materials needed for the continued life of both animals and plants are mutually provided.
Balanced terrarium (tĕ-rā′rĭ-*ŭ*m) **:** A box containing earth, in which land animals and land plants supply each other with the materials needed for continued life.
Balloon: A bag made of some light material and filled with gas or heated air so that it will rise and float in the atmosphere.
Barograph (băr′ô-gråf) **:** An instrument for recording automatically the variations of atmospheric pressure.
Barometer (b*ȧ*-rŏm′ē-tẽr) **:** An instrument for determining the pressure or weight of the atmosphere; commonly used to forecast the weather.
Base: An alkaline substance; a substance which will combine with an acid to form a salt.
Battery: A group of cells for generating electricity.
Beaker: An open-mouthed, thin glass vessel for use in laboratories.
Beam: A group of parallel rays of light.
Belt of equatorial calms: A hot and almost windless section of the earth near the equator; the heat equator.
Biceps (bī′sĕps) **:** The muscle of the upper arm that bends the forearm.
Bichloride of mercury (bī-klō′rīd) **:** A powerful germicide containing chlorine and mercury.
Bicuspid (bī-kŭs′pĭd) **:** A tooth with a blunt crown, adapted for crushing and grinding food.
Bile (bīl) **:** A secretion of the liver which aids in digestion and carries away poison from the liver.
Biplane: An airplane with two pairs of wings, one above the other.
Bituminous coal (bĭ-tū′mĭ-n*ŭ*s) **:** A soft variety of natural coal that produces much smoke in burning.
Blade: The broad, flat part of a leaf.
Blast furnace: A large steel container lined with fire brick; used for smelting ore.
Block and tackle: A device, consisting of one or more movable pulleys combined with one or more fixed pulleys, for moving weights with a small amount of effort.
Blood: The fluid which flows through the heart, arteries, and veins of the body. It consists of a colorless liquid, plasma, containing red cor-

puscles and white corpuscles. It carries oxygen and nutrients to the cells of the body and takes away wastes from them.

Botany (bŏt′ȧ-nĭ): The science which treats of plants.

Brain: The mass of nerve tissue in the cavity of the skull, forming the center of the nervous system. It consists of the cerebrum, or seat of thought, the cerebellum, which regulates the movements of the body, and the medulla, which influences respiration, circulation, and swallowing and is the connecting link with the spinal cord.

Breast wheel: A water wheel with pockets on the rim into which the water flows at a point about level with the axis of the wheel, until the added weight is sufficient to turn the wheel.

Breathing: The process by which air is taken into the lungs and carbon dioxide is removed from them.

Brick: A hard, rectangular block, usually made by baking a mixture of clay, sand, limestone, and ashes. Much used in building.

Broiling: Cooking by the direct heat of a fire.

Bronchi, or Bronchial tubes (brŏn′kī, brŏn′kĭ-ăl): Two divisions of the trachea which divide and subdivide, ending in the minute air sacs of the lungs.

Bruise: A surface injury; usually the result of a fall or blow.

Burn: An injury caused by contact with fire, a hot substance, or a strong chemical.

C

Caffein (kăf′ē-ĭn): A stimulating substance found in coffee.

Caisson (kā′sŏn): A box-like room in which men work under water. Compressed air keeps out the mud and water.

Calorie (kăl′ô-rĭ): A unit for measuring heat. One calorie (c) is the amount of heat required to raise the temperature of one gram of water 1° centigrade. It is used in scientific work. The large Calorie (C), used in measuring the heat value of foods and fuels, is equal to 1000 calories (c).

Cambium (kăm′bĭ-ŭm): The growing layer of cells in plants.

Camera: An apparatus for taking photographs by means of lenses.

Cantilever bridge (kăn′tĭ-lēv-ẽr): A bridge consisting of self-supporting framed structures built out from opposite piers and either meeting in the center or supporting a regular truss bridge between them.

Capillaries (kăp′ĭ-lā-rĭz): Small tubes that connect arteries with veins.

Capillarity (kăp-ĭ-lăr′ĭ-tĭ): The attractive force which causes liquids to rise and fill minute tubes or spaces in porous substances, as the rise of kerosene in a lamp wick.

Carbohydrate (kär-bô-hī′drāt): A food substance composed of carbon, hydrogen and oxygen. Sugar and starch are carbohydrates.

Carbolic acid (kär-bŏl′ĭk): A powerful poison; used in strong solutions as a germicide.

Carbon: A non-metallic element occurring in coal, coke and other substances; an essential part of all living things.

Carbonates (kär′bŏn-āts): Mineral substances composed mainly of carbon and oxygen; needed by the body to make protoplasm, bones, and teeth.

Carbon dioxide (dī-ŏk′sīd): A heavy, suffocating, colorless gas; a product of burning.

Carbon monoxide (mô-nŏk′sīd): A colorless, odorless, poisonous gas formed by the incomplete combustion of gasoline and other substances containing carbon.

Carburetor (kär′bŭ-rĕt-ẽr): A device for mixing air with gasoline.
Cardiac opening (kär′dĭ-ăk): The opening through which food enters the stomach from the esophagus.
Cartilage (kär′tĭ-lāj): Very tough elastic tissue, as the rings of the trachea.
Casualty (kăzh′ŭ-ăl-tĭ): An accident resulting in injury or death.
Cell: A minute mass of protoplasm usually containing a nucleus and enclosed in a cell wall; the unit of structure and function of living things; a source of electrical current.
Cell membrane: The thin covering of a cell.
Cellular (sĕl′ŭ-lȧr): Consisting of, or pertaining to, a cell or cells.
Cellulose (sĕl′ŭ-lōs): An insoluble substance forming the woody part, or walls and coverings, of cells of plants.
Cement: A powdery material usually made from ground rock containing clay and limestone, or from slag. When moistened, it sets and becomes very hard. Used in constructing roads, buildings, and other heavy structures.
Centigrade (sĕn′tĭ-grād): A thermometer scale on which the freezing point of water is 0° and the boiling point 100°.
Centrifugal force (sĕn-trĭf′ŭ-găl): The force which tends to cause a body moving in a curved path to fly off on a straight line.
Cerebellum (sĕr-ē-bĕl′ŭm): The part of the brain found between the cerebrum and the medulla; regulates the movements of the body.
Cerebrum (sĕr′ē-brŭm): The part of the brain above the cerebellum; the seat of thought.
Cesspool: A receptacle at the end of a drain to collect solid material.
Characteristic: Distinguishing mark or trait.
Charcoal: A form of coal made by heating wood in air-tight chambers.
Charging: Running an electric current through a storage cell to store in it electrical energy in the form of chemical energy.
Chemical action (kĕm′ĭ-kăl): A process by which a chemical change is brought about.
Chemical change: A change in which the nature or composition of a substance becomes new and different, as the burning of coal.
Chemical property: A property of a substance which accounts for a change in its composition. Wood has the property of burning, that is, changing to ashes and gas.
Chemistry (kĕm′ĭs-trĭ): The science which treats of the nature of substances and of what happens when substances are combined or broken up to form new substances.
Chlorination (klō-rĭ-nā′shŭn): The process of treating water with chlorine gas to kill germs in it.
Chlorine (klō′rĭn): A heavy, poisonous, greenish-yellow gas.
Choroid coat (kō′roid): The middle coat of the eye.
Chromosphere (krō′mō-sfẽr): A layer of luminous gas, mostly hydrogen, surrounding the sun.
Chronometer (krō-nŏm′ē-tẽr): A clock used in navigation.
Chyle (kīl): Chyme which has been acted upon by bile, pancreatic juice, and intestinal juice.
Chyme (kīm): Food as it leaves the stomach.
Cilia (sĭl′ĭ-ȧ): Hair-like threads of protoplasm projecting from a cell.
Circuit: Movement in a circle or orbit; complete path of an electric current.
Circulation: The movement of the blood through the arteries, veins and capillaries of the human body due to the pumping action of the heart.

Circulatory system (sûr′kû-lȧ-tô-rĭ): The system through which the blood circulates in the body. It consists of the heart, the arteries, the veins, and the capillaries.

Cirrus (sĭr′ŭs): A thin, broken, fleece-like cloud.

Civil day: A day of exactly 24 hours, running from midnight to midnight.

Clay: A common earth, soft and plastic when wet, hard when baked. Used in the making of pottery, bricks, and tiles.

Climate: The average weather conditions over a long period.

Clinical thermometer (klĭn′ĭ-kăl): A Fahrenheit thermometer in which the mercury remains at the highest temperature recorded until shaken down. Used to record bodily temperature.

Clotting: Coagulation, or thickening, of blood.

Clouds: Masses of water vapor condensed high in the air.

Coagulation (kô-ăg′û-lā-shŭn): Thickening, as the thickening of blood from a wound.

Coal: A hard, black, natural fuel composed largely of carbon.

Cocaine (kō′kȧ-ĭn): A narcotic drug made from the dried leaves of the coca plant. Used to deaden pain.

Cochlea (kŏk′lē-ȧ): A spiral tube full of liquid which transmits sound waves from the middle ear to the auditory nerve.

Codein (kô-dē′ĭn): A narcotic drug made from opium.

Coffee: A beverage containing a stimulating substance called caffein; made from the roasted seeds of the coffee plant.

Coke: Soft coal from which gaseous substances have been removed by heating; used as a fuel.

Combustion: Burning.

Comets: Heavenly bodies with bright heads and long luminous tails, which travel around the sun.

Communicable disease: A disease which can be imparted from one person to another.

Commutator (kŏm′û-tā-tẽr): A device used on a dynamo for changing an alternating current to a direct current.

Compass: An instrument used to determine direction. Its essential part is a magnetized steel needle which tends to point north and south.

Composition: The kinds and proportions of materials of which a thing is made.

Compound: A substance formed by the chemical union of two or more elements. Water is a compound of oxygen and hydrogen.

Concave: Hollowed or curved inward as the inner surface of a hollow ball.

Concrete: A mixture of cement, sand, and broken stone, moistened with water. It becomes solid, rock-like, and durable when it sets and dries. Widely used in the construction of roads, sidewalks, dams and buildings.

Condensation (kŏn-dĕn-sā′shŭn): The change from a gaseous to a liquid form, as the condensation of water vapor in forming dew.

Condenser: A device for accumulating and holding a large charge of electricity in a small space.

Conduction (kŏn-dŭk′shŭn): The flow of heat through a body, or from one body to another body through contact. The handle of a dish containing hot liquid becomes heated by conduction, as does a hand which grasps the handle.

Conductor: A substance through which heat will pass readily. A substance through which an electric current will pass readily.

Congestion: An overloading of the capillaries and other blood vessels.
Conjugation (kŏn-jo͝o-gā′shŭn): A union of two cells for reproduction.
Connective tissue: A collection of cells uniting other tissues.
Conservation of energy: The law or principle that energy can neither be created nor destroyed.
Conservation of matter: The law or principle that matter cannot be destroyed.
Constellation (kŏn-stĕ-lā′shŭn): A group of stars having a special name.
Constipation: Lack of adequate movement of the bowels.
Contagious (kŏn-tā′jŭs): Catching, as of a disease; communicable by contact.
Control: A standard, or check, for making comparisons; used in experimental work.
Convection (kŏn-vĕk′shŭn): The flow of heat through fluids by means of heat currents.
Convex (kŏn′vĕks): Curved outward, as the outer surface of a ball.
Coördination (kô-ôr-dĭ-nā′shŭn): The harmonious working together of the different parts of the body.
Cornea (kôr′nê-ȧ): The transparent part of the outer coat of the eye, which covers the iris and the pupil.
Corona (kô-rō′nȧ): A band of pearly light surrounding the sun.
Corpuscles (kôr′pŭs-'lz): Minute cells in the blood. Red corpuscles carry oxygen. White corpuscles destroy germs.
Cosmic rays: A little known form of radiant energy which comes to the earth from the space beyond our atmosphere.
Cotyledon (kŏt-ĭ-lē′dŭn): A seed leaf or leaves of a young plant containing food used to develop root, stem, and true leaves.
Cultivation of soil: The plowing and harrowing of soil to break it up so that it can better hold moisture, and to remove weeds.
Culture: A growth of bacteria on a medium.
Culture medium: A jelly-like substance on which bacteria are grown.
Cumulus (kū′mû-lŭs): A cloud form resembling heaps of wool; often brings rain and thunderstorms.
Current electricity: Flowing electricity.
Cuspid (kŭs′pĭd): A sharp, pointed tooth adapted for tearing; also called canine.
Cusps: The horns of the crescent moon.
Cyclone: The whirl of the air around an area of low pressure.
Cylinder: The chamber in a steam engine or gas engine in which expanding steam or exploding gas forces the piston to move.
Cytoplasm (sī′tô-plăz′m): The part of the protoplasm of a cell other than the nucleus.

D

Dam: A structure to hold back and store water for power, irrigation, or home supply.
Decay: To spoil, rot, or decompose; gradual loss of strength and soundness.
Decompose: To separate into simpler compounds or into elements; to rot.
Dehumidifier (dē-hû-mĭd′ĭ-fī-ẽr): A device for reducing the moisture content, or humidity, of indoor air.
Density: The closeness or compactness of the matter in a substance.
Deodorant (dē-ō′dẽr-ănt): A substance that destroys bad odors.

Dermis (dûr′mĭs): The sensitive skin below the epidermis, or outer skin of the body.
Dew: Water vapor condensed on a cool surface.
Diagnosis (dī-ăg-nō′sĭs): Decision as to the nature of a disease from its signs and symptoms.
Diaphragm (dī′ȧ-frăm): The muscular floor of the chest; the adjustable opening of a camera; the metal sound disc in telephones and radios.
Diastase (dī′ȧ-stās): A ferment in plants which changes starch to sugar.
Dicotyledon (dī-kŏt-ĭ-lē′dŭn): A plant having two cotyledons, or seed leaves, such as the bean.
Diet: A prescribed course of food intended as a health measure.
Diffused: Spread around or dispersed.
Digestion: The process of changing food in the body so it can be used to support life.
Digestive fluid: A fluid which helps change food so it can be used to nourish the body.
Digestive system: The organs in the body composing the alimentary canal, whose function is to change food into a form which can be used to support life.
Dilate (dĭ-lāt′): To grow larger.
Dilute (dĭ-lūt′): To weaken by mixing with water or some other fluid.
Diphtheria (dĭf-thē′rĭ-ȧ): A dangerous infectious disease in which the throat and air passages are affected.
Dipping needle: A magnetized steel needle balanced to rotate vertically; used to locate magnetic ore and to locate the magnetic poles of the earth.
Direct current: An electric current flowing in only one direction.
Dirigible balloon (dĭr′ĭ-jĭ-b'l): A long, pointed balloon which is propelled by engines and which can be steered.
Disease: A disordered condition of mind or body; sickness.
Disinfectant (dĭs-ĭn-fĕk′tănt): A substance used to destroy disease germs.
Dislocation: The displacement of a bone at a joint; usually the result of a blow or fall.
Dispersal (dĭs-pûr′săl): The act of spreading or scattering.
Dissolve: To absorb a solid into a liquid.
Distillation (dĭs-tĭ-lā′shŭn): The process of driving off gas or vapor from liquids or solids by heat and condensing this gas or vapor by cooling. The distilling of water to remove impurities and the making of coal gas from soft coal are illustrations.
Drug: Any substance taken as medicine; any narcotic.
Dry cell: A device to supply electric current; consists of a sealed zinc cylinder through the center of which runs a carbon rod, the space between being packed with certain chemicals.
Dry farming: The breaking up of the soil after each rainfall to retain moisture by retarding evaporation. Used in dry regions.
Dry ice: Solidified carbon dioxide gas, having a temperature of about 109° below zero; often used in place of water ice.
Ductless glands (dŭkt′lĕs): Glands whose functions are to prepare and secrete hormones directly into the blood. These include the thyroid and adrenal glands and the spleen.
Dynamo: A machine for changing the energy of motion into electrical energy; consists of a soft iron core wound with insulated wire, the armature, which, by rotating within the magnetic field of one or more U-shaped electromagnets, produces an electric current.

E

Ear: The organ of hearing.
Earth: The planet on which we live; soil.
Echo: Repetition of a sound due to reflection of sound waves.
Eclipse: The darkening of a luminous heavenly body, such as the sun, by another heavenly body passing between it and the eye; the darkening of a luminous heavenly body by another heavenly body coming between it and its source of light, as the darkening of the moon by the earth.
Efficiency: Ability to accomplish work with a minimum of effort.
Effort: Exertion of force or power to overcome resistance.
Electrical resistance: The opposition offered by a conductor, such as a wire, to the passage of an electric current through it, causing heat.
Electric cell: A device for producing a current of electricity.
Electricity: A form of energy which, under the proper conditions, will flow and exert pressure. It is divided into static, or stationary, electricity and current, or flowing, electricity. Both static and current electricity are divided into two types, positive electricity and negative electricity.
Electric motor: A machine for changing electrical energy to the energy of motion.
Electrification (ė-lĕk-trĭ-fĭ-kā′shŭn): State of being charged with electricity.
Electrodes (ė-lĕk′trōdz): The plates in an electrolysis apparatus or in an electric cell, to which the wires are attached.
Electrolysis (ē-lĕk-trŏl′ĭ-sĭs): The breaking up of a substance into its elements by means of electricity, as the decomposition of water into hydrogen and oxygen by electricity.
Electromagnet (ė-lĕk-trȯ-măg′nĕt): A piece of soft iron magnetized by the passage of an electric current through an insulated wire wound around it.
Electromotive force (ė-lĕk-trȯ-mō′tĭv): Electrical pressure in a conductor.
Electron (ė-lĕk′trŏn): A minute particle of negative electricity.
Electron theory: A theory of electricity which assumes that all atoms are made up of minute particles of positive and negative electricity. The positive particles, called protons, form the center of the atom, around which revolve the negative particles, called electrons.
Electroplating (ė-lĕk′trȯ-plāt-ĭng): The process of coating a cheaper metal with silver, gold, or some other metal by means of electricity.
Electroscope (ė-lĕk′trȯ-skōp): An instrument used to determine the presence of electricity.
Electrotyping (ė-lĕk′trȯ-tīp-ĭng): An electric process of making plates from type for use in printing.
Element: A substance which cannot be broken up into other kinds of matter. (For important elements see page 28.)
Ellipse: An oval-shaped curve having greater length than width.
Elodea (ė-lō′dė-ȧ): A water plant whose cells are much used for observing the circulation of protoplasm.
Embryo (ĕm′brĭ-ō): A young plant in the early stages of development.
Emergency: An unexpected occurrence calling for quick action.
Emetic (ė-mĕt′ĭk): A substance which will cause vomiting.
Emulsion (ė-mŭl′shŭn): A mixture of two liquids which do not unite with each other to form a true solution, as soapy water and grease.

Endosperm (ĕn′dô-spûrm): Reserve food stored in a seed outside the embryo.
Energy: Capacity for doing work.
Environment: Surroundings.
Enzyme (ĕn′zīm): Any one of the ferments in the body which aid in digestion.
Epicotyl (ĕp-ĭ-kŏt′ĭl): The part of the seedling that develops into the stem and leaves.
Epidermis (ĕp-ĭ-dûr′mĭs): The outer skin; the outermost layer of cells covering the surface of a plant.
Epiglottis (ĕp-ĭ-glŏt′ĭs): A small organ which covers the opening of the trachea, or windpipe. It opens to allow the entrance of air, and closes to keep out food.
Equator: An imaginary line around the earth halfway between the poles, dividing it into a northern and a southern hemisphere.
Equatorial calms: A belt near the equator where there is little wind.
Erosion: The act of wearing away, as rock and soil are worn away by the action of water.
Esophagus (ē-sŏf′ȧ-gŭs): The tube through which food and drink pass from the mouth to the stomach; sometimes called the gullet.
Ether: A medium which is said to fill all space.
Ethyl alcohol: Alcohol made from grains.
Eustachian tube (ū-stā′kĭ-ăn): The passage connecting the middle ear with the mouth.
Evaporate: To change from a liquid or solid state into vapor by means of heat.
Excretion (Plural—Excreta): Waste thrown off by any organism; the process of throwing off waste.
Excretory organs (ĕks′krē-tô-rĭ): Organs that give off bodily wastes.
Exhale: To breathe out, or emit.
Experiment: An attempt to discover, test, or prove some truth or principle.
Expiration (ĕk-spĭ-rā′shŭn): Breathing out.
Extensor muscle (ĕks-tĕn′sŏr): Any muscle which extends or straightens a limb.
Eye: The organ of sight.

F

Fahrenheit (fä′rĕn-hīt): A thermometer scale on which the freezing point of water is 32° and the boiling point 212°.
Fainting: Loss of consciousness caused by insufficient supply of blood to the brain.
Farsightedness: Inability to see near-by objects as clearly as distant objects.
Fatigue (fȧ-tēg′): Weariness resulting from over-working of the cells of an organism.
Fats: Energy-producing nutrients composed of carbon, hydrogen and a little oxygen.
Fauna (fô′nȧ): The native animals living within a certain region.
Fehling's solution (fā′lĭngz): A liquid used to test for the presence of grape sugar. If grape sugar is present, Fehling's solution produces a color from deep yellow to brick-red, according to the amount of grape sugar present.
Femur (fē′mŭr): The long bone of the thigh.

Ferment: Living organisms, such as yeast or bacteria, that cause the breaking up of organic matter; a chemical substance, such as the enzymes in the body, which aids digestion of food.

Fermentation: The decomposition, or breaking up, of organic matter by living organisms, such as yeasts and bacteria. Frequently accompanied by the formation of bubbles of escaping gas. The "raising" of bread dough and the formation of vinegar from cider are examples.

Fertilizer: Any substance containing plant food used to enrich the soil.

Fibers: The thread-like structures of plant and animal tissue.

Fibrin (fī'brĭn): A solid, white substance which forms when blood is clotted.

Field magnets: U-shaped magnets or electromagnets used to provide the magnetic field within which rotates the armature of a magneto, dynamo, or electric motor.

Filament (fĭl'ȧ-mĕnt): A thread-like fiber.

Filter: A device for straining any undesirable matter from a liquid.

Fire escape: A stairway or chute by which people may escape from a building in case of fire.

Fire extinguisher: A device for putting out a fire.

Fire hazard: Something dangerous on account of its liability to catch or cause fire.

Fireless cooker: A box in which hot food is placed to cook without the further use of fire.

Firing: The exposure of bricks or pottery to intense heat in order to harden or glaze them.

Fission (fĭsh'ŭn): Reproduction by dividing.

Flexor muscle (flĕk'sŏr): Any muscle which bends a limb.

Floodlight: A powerful lamp which brilliantly illuminates a wide area.

Flora (flō'rȧ): The native plants which grow within a certain region.

Flue: A passage or pipe to carry away flame and smoke. An air passage for ventilating.

Fluid: Any gaseous or liquid substance.

Focus (fō'kŭs): To bring to a central point.

Fog: Water vapor condensed in the air near the earth into small drops not heavy enough to fall.

Food: Material for the growth, repair or energizing of any living body.

Foot pound: The amount of work done in lifting a pound avoirdupois through a distance of one foot.

Force: The use of energy in the effort to do work. Energy which tends to produce motion or a change of motion in a body.

Forestry: The science of cultivating and caring for forests.

Formaldehyde (fôr-măl'dē-hīd): A gaseous compound having a sharp penetrating odor; used as a disinfectant and preservative.

Fossil: A rock form of a plant or an animal which in past ages left a mold of itself which became filled with rock-forming material.

Fracture: The breaking of a bone in the body.

Frequency: Rate of occurrence, as of light waves.

Friction: Resistance encountered when a surface is rubbed over another surface.

Frigid zone: The part of the earth between either polar circle and its pole.

Frost: Minute ice crystals formed in place of dew at 32° F. or below.

Fruit: The seed-bearing part of a plant.

Frying: Cooking in hot fat.

Fuel: Any material used to provide heat by burning.

Fuel oil: A product of petroleum; used as a fuel.
Fulcrum (fŭl′krŭm): The support on which a lever turns.
Fumigation: Disinfection by poisonous fumes or gases.
Function: The normal action of any organ or set of organs.
Fungus (fŭn′gŭs): A plant which cannot make its own food but feeds on the tissues of other plants. Yeasts, molds, and toadstools are fungi.
Fuse: A short piece of metal with a low melting point; used as a safeguard against too great an electric current.
Fusing: The melting and blending together of two or more substances when heated.
Fusion (fū′zhŭn): The combining of two substances by melting.

G

Gall bladder: A bag-like organ attached to the liver, which stores bile.
Galvanometer (găl-vȧ-nŏm′ē-tẽr): An instrument for detecting an electric current and for measuring its intensity and direction.
Ganglia (găn′glĭ-ȧ): Collections of nerve cells and fibers from which nerves branch out, such as the ganglia of the sympathetic system.
Gas: A freely flowing fluid, such as air, which tends to expand indefinitely to fill any container in which it is confined.
Gas engine: An engine in which an explosive mixture of gasoline vapor and air is burned in the cylinder itself, the explosion serving to move a piston within the cylinder.
Gaseous: In the form of gas.
Gasoline: A very volatile and inflammable mixture of fluid hydrocarbons obtained from petroleum. Used as a fuel in gas engines.
Gastric glands: Digestive glands in the walls of the stomach.
Gastric juice: The chief digestive fluid of the stomach.
Gelatin: A jelly extracted from animal tissues by boiling.
General property: A quality which is common to all forms of matter.
General Science: The science which treats of our surroundings.
Generator: A machine for changing the energy of motion to electrical energy; a dynamo.
Genus (jē′nŭs): A group of related species. For example, the zebra and horse belong to one genus.
Geology (jē-ŏl′ō-jĭ): The science which treats of the structure and history of the earth.
Germicide: A chemical preparation used to kill germs.
Germinate: To sprout, as does a seed.
Germs: Common name for bacteria or protozoa which cause disease.
Glacial deposits (glā′shăl): Material left by glaciers.
Glacier: A large field or stream of ice and snow moving down a mountain slope or over an extended area.
Glands: Organs which secrete material to be used in the body, such as the salivary glands, or which excrete waste, such as the kidneys.
Glottis: The opening at the top of the windpipe.
Glucose (glōō′kōs): A sweet substance used as an adulterant in place of sugar.
Glycogen (glī′kō-jĕn): A form of sugar stored in the liver; used to supply energy for the contraction of muscles.
Granite: A hard, durable, igneous rock; used for building.
Granular: Formed of tiny separate grains.
Grape sugar: A white, crystalline form of sugar of about one-half the sweetness of cane sugar. Found in grapes and other fruits. The digestive fluids of the body change starch into grape sugar.

Gravitation: The attractive force by which all bodies of matter in the universe are drawn toward each other.
Gravity: The attractive force which tends to draw all bodies toward the center of the earth.
Gray matter: The gray nerve tissue, consisting mainly of nerve cells, forming a thin outside covering of the cerebrum and cerebellum and the inside portion of the medulla and the spinal cord.
Gullet: The food passage extending from the mouth cavity to the stomach; the food passage of the paramecium.
Gyro-compass (jī′rô): An application of the gyroscope used in place of the magnetic compass on ships and aircraft.
Gyroscope (jī′rô-skōp): A heavy metal wheel, mounted in a metal frame. When spinning rapidly, a gyroscope tends to keep its original position and to resist any force to change this position.
Gyrostabilizer (jī-rô-stā′bĭ-līz-ẽr): An application of the gyroscope by which ships and airplanes may be kept on an even keel.

H

Hail: Ice particles formed by the freezing of raindrops.
Heart: A hollow, conical, muscular organ which pumps blood through the circulatory system.
Heat: A form of energy resulting from the motion of molecules.
Heat equator: The belt of equatorial calms.
Heating systems—
- **Hot air system**: The method of heating a building by means of currents of warm air conducted from a furnace to the various rooms through metal tubes.
- **Hot water system**: The method of heating a building by means of hot water conducted from a boiler through pipes to radiators in the various rooms.
- **Steam heating system**: The method of heating a building by means of steam conducted from a boiler through pipes into radiators in the various rooms.

Heavens: The sky.
Helium (hē′lĭ-ŭm): A light, non-inflammable gas used in airships.
Helix (hē′lĭks): A coil of insulated wire wound around the iron core of an electromagnet.
Hemoglobin (hē-mô-glō′bĭn): Coloring matter of the red corpuscles of the blood; contains iron which attracts oxygen.
Hemorrhage (hĕm′ŏ-râj): Discharge of blood from a blood vessel; bleeding.
Heredity (hê-rĕd′ĭ-tĭ): Transmission of qualities from parent to child.
Heroin (hê-rō′ĭn): A narcotic drug made from opium and from coal tar.
Hertzian waves (hĕrt′sĭ-ăn): Waves in ether caused by the vibratory motion of an electrical discharge. Radio waves are Hertzian waves.
Hibernation (hī-bẽr-nā′shŭn): The act of passing the winter in a state of sleep or inactivity, as do certain animals and plants.
"High": On a weather map, "high" indicates the centers of highest barometric pressure. It usually means fair weather.
Hilum (hī′lŭm): Scar on a seed at the point where it was attached to the parent plant.
Horizon: The line where the earth and sky seem to meet.
Hormones (hôr′mōnz): Chemical secretions of the ductless glands, which arouse other organs to greater activity.

Horse latitudes: High pressure areas near the tropics of Cancer and Capricorn; caused by the descending air from the belt of equatorial calms.
Horse power: The rate of doing work based on what it was thought the average horse could do. One horse power is equivalent to the power necessary to raise 33,000 pounds one foot in one minute.
Humidifier (hû-mĭd'ĭ-fī-ẽr): A device for moistening air.
Humidistat (hû-mĭd'ĭ-stăt): A device for regulating automatically the humidity of indoor air.
Humidity (hû-mĭd'ĭ-tĭ): The degree of moisture in the air.
Humus (hū'mŭs): The dark part of soil formed by the decay of vegetable and animal matter.
Hurricane: A violent whirlwind of great width generally accompanied by rain, thunder and lightning; usually originates in the tropics.
Hydro-airplane (hī'drȯ): An airplane equipped with boat-like floats for landing on and taking off from the surface of water.
Hydrocarbon: A combustible compound containing hydrogen and carbon, such as benzine.
Hydrogen (hī'drȯ-jĕn): A colorless, odorless, tasteless, inflammable gas. The lightest substance known. One of the elements.
Hygiene (hī'jĭ-ēn): The science of health.
Hygrometer (hī-grŏm'ė-tẽr): An instrument for measuring the degree of moisture in the air.
Hypocotyl (hī-pȯ-kŏt'ĭl): The first root and stem of a sprouting seed.
Hypothesis (hī-pŏth'ė-sĭs): A principle not proved but assumed for the purpose of argument.

I

Igneous rocks (ĭg'nė-ŭs): Rocks cooled from a molten mass. Granite is an example.
Immunity (ĭ-mū'nĭ-tĭ): The state of being not susceptible to a disease.
Incandescent (ĭn-kăn-dĕs'ĕnt): Glowing or luminous with intense heat.
Incandescent lamp: A glass bulb containing a thin wire filament which becomes heated and gives off light when an electric current passes through it.
Incised wound (ĭn-sīzd'): A cut, usually made by a knife or glass.
Incisor (ĭn-sī'zẽr): A tooth with a sharp, chisel-like edge, well adapted for cutting.
Inclined plane: A sloping surface. One of the simple basic machines.
Induced current: A current of electricity generated in a coil of insulated wire by rotating it within the magnetic field of a magnet, or by moving a magnet within the coil.
Induced magnetism: Magnetism created in a piece of iron by contact with, or nearness to, a magnet.
Inductance coil: A device in a radio sending set for regulating wave length.
Inertia (ĭn-ûr'shĭ-ȧ): A property of matter by which it tends, when at rest, to remain at rest, and when in motion, to continue in motion.
Infection: The taking of a disease from germs introduced into the body either by direct contact with a diseased person or through the air or other germ-bearing medium.
Inflammable (ĭn-flăm'ȧ-b'l): Easily set on fire.
Infra-red rays (ĭn'frȧ): Light rays having a longer wave length than red light; they are invisible to the human eye.
Inhale: To breathe in.

Inoculate (ĭn-ŏk′ū-lāt): To put infectious matter into the flesh of a person to protect him against a disease.
Inorganic (ĭn-ŏr-găn′ĭk): A term applied to matter that is and always has been lifeless.
Insect: A small creature without a backbone. Its body is divided into three segments.
Insoluble (ĭn-sŏl′ū-b′l): Incapable of being dissolved.
Inspiration: Act of breathing in.
Insulation (ĭn-sû-lā′shŭn): Act of separating a body from others by non-conducting material so as to prevent the transfer of electricity or heat.
Insulin (ĭn′sŭ-lĭn): A secretion of the pancreas necessary for the assimilation of sugar.
Integument (ĭn-tĕg′ū-mĕnt): A thin inner covering in some seeds.
Intensity: Degree or amount, as, for example, of sound.
Intestinal juice: A ferment in the small intestine which neutralizes acids and aids digestion.
Intestine: The tube in vertebrates through which food passes after leaving the stomach; divided into the small and the large intestines.
Involuntary muscles: Muscles which perform movements not under the guidance of the will, such as the beating of the heart.
Iodine: A chemical substance prepared from a seaweed. In solution it is used as a test for starch and as a disinfectant.
Iris: The adjustable diaphragm of the eye which regulates the amount of light striking the lens.
Iron: A solid, heavy, grayish-white metal. One of the elements.
Irrigate: To moisten the land for agriculture by causing water to flow over or through it.
Isobar (ī′sô-bär): A line on a weather map connecting the places where the atmospheric pressure is the same at a given time.
Isolated (ī′sô-lāt-ĕd): Separated from others; put by itself.
Isotherm (ī′sô-thûrm): A line on a weather map connecting places in which the temperature is the same at a given time.

J

Jacketed stove: A stove surrounded by a wall of sheet iron, which serves to distribute heat more evenly.

K

Kerosene: An oil used for lighting purposes; obtained from petroleum.
Kidneys: The two glands which excrete urine.
Kilowatt (kĭl′ô-wŏt): A unit of power in electrical measurement which is equal to 1000 watts.
Kilowatt hour: The amount of work done by one kilowatt, 1000 watts, of electric current in one hour.
Kindling temperature: The temperature at which a substance will take fire.
Kinetic energy (kĭ-nĕt′ĭk): The energy of motion.

L

Lacerated wound (lăs′ẽr-āt-ĕd): A wound in which the skin and the tissues beneath are torn instead of cut.
Lacteals (lăk′tê-ălz): Tube-like channels which carry fats from the small intestine to the thoracic duct.

Larva: The young of certain insects in an early stage in life. The caterpillar is the larval stage of the butterfly or moth.

Larynx (lăr′ĭnks): The upper part of the windpipe; the voice box.

Latent energy (lā′tĕnt): Energy not active but capable of activity; potential energy. For example, the energy of stored water in a high place.

Latitude: Distance in degrees north or south of the equator.

Law: A generally accepted explanation of some natural occurrence.

Law of electrical charges: Unlike electrical charges attract each other, and like charges repel each other.

Law of magnetic poles: Like poles of magnets repel each other, and unlike poles attract each other.

Lead: A solid, heavy, soft, bluish-gray metal, easily melted. One of the elements.

Legumes (lĕg′ūmz): Pod-bearing plants or their seeds. Peas and beans are examples.

Lens: A transparent piece of glass so made that its surfaces are not parallel and at least one is curved. Used, for example, in glasses for spreading or focusing light rays. The portion of the eye that focuses light rays on the retina.

Lenticels (lĕn′tĭ-sĕlz): Tiny openings in the bark of a woody plant through which oxygen enters.

Lever (lē′vẽr): A rigid bar arranged to turn upon a fixed support or axis called a fulcrum; divided into three classes according to the position of the fulcrum.

Leyden jar (lī′dĕn): A device for storing static electricity.

Life process: Any function of living things necessary for existence.

Ligament (lĭg′ȧ-mĕnt): A tough band of tissue serving to connect two bones, or to hold an organ in place.

Light: A form of energy received from the sun or other illuminating body, which acts on the eyes to cause sight.

Lightning: The discharge between two clouds bearing unlike electrical charges or between clouds and oppositely charged objects on the earth. The vivid flash of light caused by such a discharge.

Light year: The distance which light travels in one year at the rate of 186,000 miles a second. Used to measure distances in the heavens.

Lines of force: Imaginary lines indicating the shape and extent of a magnetic field.

Liquefy: To change from a solid to a liquid form.

Liquid: A freely flowing fluid, such as water, which tends to take the shape of any container in which it is placed.

Litmus paper: A special paper used to find out whether a substance is acid or alkaline. Acids turn blue litmus paper red. Alkalies turn red litmus paper blue.

Liver: A gland which secretes bile and stores glycogen used by the body muscles.

Loam: A soil in which there is a combination of clay, sand, and humus.

Lodestone: Magnetic iron ore, magnetite, a natural magnet.

Longitude: Distance in degrees east or west from a given meridian.

Loud speaker: The part of a radio receiving set that changes waves of electric energy into sound waves, which it magnifies.

"Low": On a weather map "low" indicates the centers of lowest barometric pressure. In a "low" area the weather is usually cloudy or rainy.

Luminous: Emitting or reflecting light; shining.

Lungs: Two sponge-like organs composed of minute air tubes, air sacs, and capillaries. Located in the chest and used in breathing.

Lye: An alkali used in making soap.

Lymph (lĭmf): The part of the blood plasma which escapes from the capillaries into the spaces between the cells. It gives off nutrients to the cells and receives wastes, part of which it carries off through the lymphatics, a vein-like system discharging into the blood through the thoracic duct.

Lymphatics (lĭm-făt'ĭks): The system of pipe-like vessels which carries the lymph.

M

Macadam road (mă̆k-ăd'ăm): A road constructed of several inches of broken stone, overlaid with thin layers of fine stone and stone dust, the surface being curved to shed water and rolled. Often coated with tar compounds to bind the fine stone material together.

Machine: A device for transforming and applying energy, and for making work easier or less burdensome.

Magnet: A piece of metal which will attract and hold to itself bits of iron and steel.

Magnetic field: The space around a magnet which is influenced by its force.

Magnetic needle: A slender bar of magnetized steel, suspended on a pointed pivot, which tends to point north and south. The essential part of a compass.

Magnetism: A form of energy exercised by magnets in attracting iron and steel.

Magneto: A dynamo in which the magnets are permanent magnets rather than electromagnets.

Malnutrition (măl-nū-trĭsh'ŭn): Lack of proper nourishment of the body.

Mammals: Animals which nourish their young with their own milk.

Mantle: A small fiber bag coated with a solution of thorium; used over a gas, kerosene, or gasoline flame to give a better light.

Marble: A form of limestone capable of a high polish; used for building and ornamental purposes.

Masticate: To chew.

Matter: Any material of which things are made or which occupies space.

Mean temperature: Average temperature.

Mechanical advantage: The efficiency of a machine as measured by the force it exerts divided by the force applied to it.

Mechanical energy: The energy of motion; kinetic energy.

Medium: A substance through which a force is transmitted, as air is a medium for carrying sound. A substance upon which bacteria colonies are developed.

Medulla (mē-dŭl'ȧ): A wedge-shaped organ, the connecting link between brain and spinal cord, which controls the action of the respiratory system, the contraction of arteries, and the movements of the esophagus in swallowing.

Membrane: A thin, pliable sheet or layer of animal tissue; a lining or covering of the organs of the body, as the mucous membrane.

Meningitis (mĕn-ĭn-jī'tĭs): Inflammation of the membranes which envelop the brain and spinal cord.

Mercury: A fluid, white, heavy metal. One of the elements.

Meridians: Imaginary lines on the earth's surface extending directly from pole to pole.
Metamorphic rocks (mĕt-*ȧ*-môr′fĭk): Rocks formed from sedimentary rocks under high pressure and its resulting heat. Marble is an example.
Metamorphosis (mĕt-*ȧ*-môr′fȯ-sĭs): A marked change in the form of a living organism by a natural process of development, as the change of a caterpillar to a butterfly.
Metazoa (mĕt-*ȧ*-zō′*ȧ*): Many-celled animals. Man and all of the higher animals are metazoa.
Meteor (mē′tḗ-*ŏ*r): A luminous body moving rapidly through the upper atmosphere; a shooting star.
Meteorograph (mē′tḗ-*ŏ*r-ȯ-gråf): An instrument which records atmospheric pressure, rainfall, temperature, and humidity.
Meteorology (mē-tḗ-*ŏ*r-ŏl′ȯ-jĭ): The science of the weather.
Methyl alcohol (mĕth′ĭl): A poisonous alcohol made from wood fiber; wood alcohol.
Microbe (mī′krōb): A germ.
Microörganism (mī-krȯ-ôr′g*ă*n-ĭz′m): An organism too small to be seen without a microscope.
Microphone (mī′krȯ-fōn): The part of a radio sending set that receives the sound waves to be broadcast.
Micropyle (mī′krȯ-pīl): A little opening in a seed through which pollen grains grow into the ovule, and through which the hypocotyl comes out.
Microscope (mī′krȯ-skōp): An instrument which makes minute objects visible by means of lenses.
Midrib: The central or main rib of a leaf.
Migrate: To go from one climate to another at certain seasons of the year, as the seasonal migration of birds.
Milky way: A luminous cloud-like band composed of millions of faint stars, seen stretching across the sky at night.
Mineral: Any substance that is neither animal nor vegetable.
Mixture: A physical combination of two or more elements in which none of them loses its identity.
Molar: A tooth with a broad, rough, uneven surface; adapted for crushing and grinding food.
Mold: A low form of plant life belonging to the fungus class. The mold which forms on bread is an illustration.
Molecular theory (mȯ-lĕk′ū-l*ȧ*r): The theory that all matter is composed of tiny particles called molecules.
Molecule (mŏl′ḗ-kūl): The smallest particle into which a substance can be divided and still be the same kind of substance.
Momentum (mȯ-mĕn′t*ŭ*m): The combined effect of the weight and speed of a moving body which makes it difficult to stop.
Monocotyledon (mŏn-ȯ-kŏt-ĭ-lē′d*ŭ*n): A plant having one cotyledon, or seed leaf, such as corn.
Monoplane: An airplane with a single pair of wings.
Moon: A spherical body which revolves about the earth and shines by the reflected light of the sun.
Morphine (môr′fĭn): A narcotic drug made from opium.
Morse code: An alphabet in which combinations of dots and dashes represent letters and numbers. Used in sending telegraph and wireless messages.
Motion pictures: Pictures showing successive positions of moving figures and objects. When projected upon a screen in rapid succession they give the impression of natural and realistic motion.

Mucous membrane (mū′kŭs): A thin moist membrane lining all body passages which have an external opening.

Muscles: Tissues which can move parts of the body by contraction; the organs of motion.

N

Naphtha (năf′thȧ): A product of petroleum; used for light and heat.

Narcotic (när-kŏt′ĭk): A drug which lessens the activity of the organs.

Nature: The universe and the forces at work in the universe.

Navigation: The steering, directing, and managing of a ship or aircraft on its course from one point to another.

Nearsightedness: Inability to see distant objects clearly.

Neon tube (nē′ŏn): An incandescent tube filled with neon gas which glows when an electric current passes through it.

Nerves: Thread-like organs which form a means of communication between all parts of the body and the brain. Those which carry messages from the organs to the brain are called sensory nerves. Those which carry orders from the brain to any part of the body are called motor nerves.

Nervous system: A system, consisting of brain, spinal cord, and nerves, which controls and directs the processes of the body and enables the body to adjust itself to its surroundings.

Netted-veined leaf: A leaf in which the veins are so branched as to form a network.

Neuron (nū′rŏn): A nerve cell and its branches; the unit of the nervous system.

Neutral substances: Substances having neither acid nor alkaline properties. Table salt is an example.

Nicotine (nĭk′ō-tĭn): A very poisonous, oily liquid found in tobacco.

Nimbus: A dark gray cloud which brings rain.

Nitrates (nī′trāts): Soluble compounds containing nitrogen. Certain nitrates are valuable as plant food to supply the nitrogen needed.

Nitrogen (nī′trō-jĕn): An odorless, colorless, tasteless gas; neither burns nor supports combustion. Found in the earth, the air, and in plants and animals.

Nitrogen-fixing bacteria: A class of bacteria found on the roots of plants, which take free nitrogen from the air and change it into a form which the root hairs of plants can absorb.

Nucleus (nū′klē-ŭs): The central rounded portion of the protoplasm in a cell, considered vital to growth and development. The center of the sun. The center of an atom, consisting of tiny positive protons of electricity about which revolve the negative electrons.

Nutrient (nū′trĭ-ĕnt): A food substance which promotes growth.

Nutriment (nū′trĭ-mĕnt): Anything which promotes growth and repairs waste in living things.

Nutrition (nū-trĭsh′ŭn): The processes by which living things use food to repair waste tissues and promote growth.

O

Ohm (ōm): The unit of electrical resistance, approximately equal to the resistance of 157 feet of number 18 copper wire.

Oil: A lubricating liquid used to reduce friction in machines. A nutrient found in certain foods.

Oil burner: A burner which vaporizes and burns fuel oil; used in connection with furnaces, ranges, and certain types of engines.

Opaque (ȯ-pāk′): Not permitting the passage of light.
Opium: A powerful narcotic drug made from the juice of the unripe seed capsules of the white poppy.
Optic nerve: The nerve by which sight impulses pass from the retina of the eye to the brain.
Orbit: The path followed by a heavenly body in its revolution.
Ore: A mineral substance containing one or more valuable metals, for example, iron ore or gold-bearing rock.
Organ: A collection of tissues for doing a special work.
Organic (ŏr-găn′ĭk): A term applied to material that has or once had life.
Organism (ôr′găn-ĭz′m): A body composed of organs essential to life; any living thing.
Oscillate (ŏs′ĭ-lāt): To move to and fro.
Osmosis (ŏs-mō′sĭs): The passing of liquids or gases through a membrane.
Overshot wheel: A water wheel in which water flows on top of the wheel and fills large pockets on the rim until the added weight is sufficient to turn the wheel.
Ovule (ō′vūl): An egg cell of a seed plant.
Oxidation (ŏk-sĭ-dā′shŭn): Burning; the uniting of oxygen with any other substance.
Oxide (ŏk′sīd): The substance formed when oxygen unites with any other substance.
Oxygen (ŏk′sĭ-jĕn): A colorless, odorless, tasteless gas essential to life. Supports combustion. One of the elements.

P

Palate: The roof of the mouth.
Palmate leaf (păl′māt): A netted-veined leaf of palm-like form.
Pancreas (păn′krė-ăs): A gland connected with the alimentary canal, secreting a digestive fluid called pancreatic juice.
Papillæ (pȧ-pĭl′ē): Minute projections on the upper surface of the tongue. The organs of taste.
Parachute: An umbrella-like device for use in emergency descents from balloons or airplanes.
Parallels: Imaginary lines around the earth parallel to the equator.
Parallel-veined leaf: A leaf in which the veins are parallel.
Paramecium (păr-ȧ-mē′shĭ-ŭm): A one-celled animal.
Parasite (păr′ȧ-sīt): A plant or animal which lives on or in another live plant or animal and feeds upon it or its food. Lice, tapeworms, and fungi are parasites.
Parotid glands (pȧ-rŏt′ĭd): A pair of salivary glands lying in the cheeks just in front of the ears.
Pasteurization (pȧs-tẽr-ĭ-zā′shŭn): Partially sterilizing by heat at a temperature high enough to destroy most but not all bacteria.
Peat: A substance of vegetable origin found in bogs and used for fuel.
Pectoral girdle (pĕk′tō-răl): The bony arch supporting the arms.
Pelton wheel: A water wheel on whose rim are cup-shaped buckets. A stream of water forced under high pressure against the buckets from underneath turns the wheel.
Pelvis: The bony hip girdle which supports the spine and to which the lower limbs are attached.
Pencil of light: A number of rays which come together at a point.

Penumbra (pė-nŭm′brȧ): The lighter part of a shadow.
Pepsin: A ferment in gastric juice which helps change protein food to a soluble form.
Pericardium (pĕr-ĭ-kär′dĭ-ŭm): The membrane which encloses the heart.
Peristalsis (pĕr-ĭ-stăl′sĭs): The wave-like, muscular action which forces food through the alimentary canal.
Peritoneum (pĕr-ĭ-tȯ-nē′ŭm): The membrane lining the walls of the abdomen and the outside of the stomach.
Petiole (pĕt′ĭ-ōl): The stem of a leaf.
Petri dish (pā′trē): A dish used to hold a medium on which to grow bacteria.
Petroleum (pė-trō′lė-ŭm): Mineral oil; a dark-colored, inflammable liquid found by drilling into the earth.
Pharynx (făr′ĭnks): The cavity at the back of the mouth, which leads to the esophagus.
Phases of the moon: The constantly changing forms in which the moon is seen, such as half moon, full moon, and crescent.
Phenomenon (fė-nŏm′ė-nŏn): Any fact or event which can be observed by the senses.
Phonograph: A machine for reproducing sounds recorded on a record.
Phosphate: A mineral substance needed by the body; a fertilizer containing phosphorus.
Phosphorus: A solid, yellowish, wax-like, inflammable substance that readily absorbs oxygen from the air. One of the elements.
Photoelectric cell (fō-tȯ-ė-lĕk′trĭk): An electric device used to vary the strength of an electric current to correspond to variations in the intensity of a beam of light.
Photosphere (fō′tȯ-sfēr): The part of the sun which we commonly see, consisting of brilliantly burning gas.
Photosynthesis (fō-tȯ-sĭn′thė-sĭs): The making of carbohydrate food in the green leaves of a living plant exposed to the sun.
Physical change: A change in which the nature or composition of a substance remains the same, as logs made into lumber.
Physical culture: Systematic exercise of the muscular system.
Physical geography: The science which treats of the earth's surface and its history.
Physical property: Any property of a substance that can be observed by the senses of sight, hearing, taste, touch, or smell.
Physicist (fĭz′ĭ-sĭst): A specialist in the science of physics.
Physics: The science which treats of mechanics, heat, electricity, light and sound.
Physiological division of labor (fĭz-ĭ-ȯ-lŏj′ĭ-kăl): Performance of various kinds of work by different parts of an organism.
Physiology (fĭz-ĭ-ŏl′ȯ-jĭ): The science which treats of our bodies.
Piano player: A piano played by air pressure.
Pinnate leaf (pĭn′āt): A netted-veined leaf of feather-like form.
Piston: A sliding solid cylinder within a larger hollow cylinder, moved either by expanding gas or steam, as in an engine, or by hand or other force, as in a pump.
Pith: A very light, woody, substance; the central part of a stem.
Planet: A large, spherical body that revolves around the sun, such as the earth.
Plant: Any vegetable growth.
Plasma (plăz′mȧ): The liquid part of the blood.
Platinum: A solid, very heavy, silvery metal. One of the elements.

Pleura (plōō′rȧ): The membrane which covers the lungs.
Plumbing: The pipes and fittings in a building for water supply and sewage disposal.
Plumule (plōō′mūl): The part of an embryo which develops above the cotyledon into the stem and leaf.
Point of saturation: The point at which air at a given temperature contains all the moisture it can possibly hold.
Polarity (pō-lăr′ĭ-tĭ): The tendency of a magnet to assume a north and south direction when suspended.
Pole: Either end of a magnet or of the earth's axis.
Pollen: A powder-like substance found in flowers and necessary to the development of their seeds.
Pollination: The transfer of pollen in flowers.
Pollute (pŏ-lūt′): To make unfit for use.
Porcelain: A semi-translucent kind of earthenware.
Porous: Full of small holes or spaces.
Portal circulation: The circulation of the blood through the liver; a part of the systemic circulation.
Portal vein: A large vein which carries blood from the capillaries in the walls of the small intestine to the liver.
Potassium: A soft white metal which reacts violently with water.
Potential (pō-tĕn′shăl): The amount of electrical pressure at a given point in an electrical circuit.
Potential energy: Possible energy; energy which exists but is not active; same as latent energy.
Power: Capacity to do work; rate of doing work.
Precipitate (prē-sĭp′ĭ-tāt): A solid which separates out when two solutions are mixed.
Precipitation (prē-sĭp-ĭ-tā′shŭn): A fall of rain, hail, or snow.
Preserve: To keep from injury or from decay.
Pressure: The action of a force against an opposing force.
Primary colors: The seven colors of the spectrum—red, orange, yellow, green, blue, indigo, and violet; in painting—red, yellow and blue.
Principle of moments: In a lever the weight multiplied by the weight arm equals the effort multiplied by the effort arm.
Proboscis (prō-bŏs′ĭs): The feeding tube of insects.
Propeller: Two or more blades set at an angle on a shaft; used to propel a ship or an airplane.
Property: A quality of a substance.
Protein (prō′tē-ĭn): A nutrient composed mainly of nitrogen; essential for the growth and repair of living tissues.
Proton (prō′tŏn): A minute particle of positive electricity.
Protoplasm (prō′tō-plăz′m): A thin, nearly transparent fluid of which all living cells are made.
Protozoa (prō-tō-zō′ȧ): One-celled animals.
Pseudopods (sū′dō-pŏdz): Projections of protoplasm which form the false feet of some one-celled animals.
Ptomaine (tō′mā-ĭn): A substance formed by the decomposition of organic matter; often poisonous.
Ptyalin (tī′ȧ-lĭn): A ferment in the saliva which helps digest starchy foods.
Pulley: A grooved wheel turning within a frame or block by means of a cord or rope passing over it. One of the basic machines.
Pulmonary circulation (pŭl′mō-nā-rĭ): The circulation of the blood through the lungs.

Pulmotor: A device for pumping air into and out of the lungs; used in artificial respiration.
Pulse: Throbbing of the arteries caused by the wave-like motion of the blood within them.
Punctured wound: A deep wound with a small opening, such as from the stab of a sharp instrument or from a bullet.
Pupa (pū′pȧ): The young of certain insects in the sleeping stage of their development that precedes the adult stage. The cocoon holds the pupa of the moth.
Pupil: The adjustable opening of the eye through which light passes to reach the lens.
Putrefaction (pū-trē̇-făk′shŭn): Offensive state of decay.
Pylorus (pĭ-lō′rŭs): The opening from the stomach into the small intestine.
Pyorrhea (pī-ŏ-rē′ȧ): A disease of the gums which causes loss of teeth.

Q

Quarantine (kwŏr′ăn-tēn): Separation from other people of those who have an infectious disease or who have been exposed to it.

R

Radiant energy: Energy received from the sun, including both light and heat energy.
Radiation: The flow of heat from a body in straight lines in all directions.
Radiator: A number of connected loops of pipe in a steam or hot water plant, which give off heat by radiation.
Radio: A method of wireless communication by which sound is sent and received in the form of waves in the ether.
Radio beacon: An automatic radio sending set which broadcasts signals to guide ships and airplanes on their courses.
Radiometer (rā-dĭ-ŏm′ē̇-tẽr): An instrument for detecting the presence of and measuring the intensity of small amounts of heat energy.
Radium: A rare metallic element which spontaneously gives off rays containing particles of the material itself; found in minute quantities.
Rain: Drops of water formed by the condensation of water vapor in the air.
Rainbow: A natural spectrum stretching in an arc across the sky; formed by the breaking up of sunlight as it passes through raindrops.
Rain gauge: A device for measuring the quantity of rainfall.
Ray: A single line of light too small to be seen.
Rayon: Artificial silk made from wood pulp.
Receiver: The earpiece of a telephone which receives messages.
Red corpuscles (kôr′pŭs-’lz): Small red cells in the blood which convey oxygen from the lungs to the cells of the body.
Reflection: The turning back of light or sound from an object.
Reflex action: Action directed by the spinal cord without the aid of the brain. Aids as a protection against injury and relieves the brain of work.
Reforestation: The replacing of used forests with new growth.
Refraction: The bending of a beam of light when it passes at an angle from one medium into another of different density.

Refrigeration: The preserving of foods by keeping them at a low temperature, thus hindering the growth of molds and bacteria.

Relative humidity (hū-mĭd′ĭ-tĭ): The ratio between the amount of moisture in the air at a given time and temperature and the maximum amount it could hold at that temperature; usually expressed in terms of percentage.

Relay (rē-lā′): A device for increasing the strength of the electric current which operates the sounder in a telegraph circuit.

Rennin: A ferment in gastric juice which coagulates milk.

Reproduce: To form similar matter.

Reservoir: A place where water is stored for use.

Resistance: Opposition, as that offered by a wire to the passage of an electric current.

Respiration: The taking in of oxygen by a plant or animal, the combining of this oxygen with digested food material, and the excretion of carbon dioxide.

Respiratory (rē-spīr′ȧ-tō-rĭ): Pertaining to breathing.

Retina (rĕt′ĭ-nȧ): The inner coating of the eye which receives pictures of objects, called images, and transmits them through the optic nerve to the brain.

Retort: A closed, air-tight chamber in which wood, coal, and other substances are subjected to heat to make charcoal, coke, gas and other products.

Revolution: The act of passing around a body in a regular orbit.

Ribs: A series of twelve pairs of curved bones, which serve to protect the chest cavity.

Roasting: Cooking by exposing to continued high temperature, as in an oven.

Rock: The inorganic material which forms the solid part of the earth.

Root: The underground part of a plant.

Root hair: A tiny offshoot of a root where absorption takes place.

Rotation: The act of turning around on an axis or center.

Rotation of crops: Raising of a series of different crops on the same land in different years.

Rust: Iron which has oxidized.

S

Saccharin (săk′ȧ-rĭn): An intensely sweet drug obtained from coal tar; often used as an adulterant for sugar.

Saliva: The secretion of the salivary glands; aids digestion.

Salt: A neutral substance formed by the action of an acid with an alkali. A seasoning for food.

Sand: A loose material consisting of fine particles of rock. Used in glass making and concrete.

Sandstone: A sedimentary rock consisting of sand grains held together by a material containing clay or silica; used for building.

Sanitary: In a healthful condition; free from germs.

Sanitation: The application of measures for promoting and protecting health.

Saprophyte (săp′rō-fīt): A plant, such as a mushroom or an Indian pipe, which lives on dead and decaying vegetable matter.

Satellite (săt′ĕ-līt): A small planet revolving about a larger one; a moon.

Saturate (săt′ū-rāt): To soak.

Saturated solution: A liquid which has dissolved as much of a soluble substance as it can hold.
Scald: An injury caused by contact with steam or boiling water.
Scanning disk: A circular piece of metal pierced by a spiral series of holes; an essential part of a television sending apparatus.
Scavenger: Any animal which devours refuse.
Schaefer method (shā'fẽr): An efficient method of artificial respiration to overcome suffocation; consists of the alternate application and release of pressure from behind on the lower ribs.
Schick test (shĭk): A test to show whether one is susceptible to diphtheria.
Science: Classified knowledge of the facts about nature.
Scientific method: The definite experimental plan by which scientists work, involving observation, comparison, and conclusion.
Sclerotic coat (sklē-rŏt'ĭk): The opaque outer coat which covers all of the eye except the iris and the pupil.
Screw: A form of the inclined plane, consisting of a continuous groove or ridge wound at an angle about a cylinder. One of the basic machines.
Screw propeller: Two or more metal blades, resembling the blades of an electric fan, set at an angle on a shaft, and located at the stern of a ship below the water line. The pressure of the revolving blades against the water moves the ship.
Searchlight: A powerful lamp which throws a long, narrow beam of light a great distance.
Secrete (sē-krēt'): To produce and give off. The liver secretes bile.
Sedentary (sĕd'ĕn-tā-rĭ): Seated; obtaining little exercise, as the sedentary life of an accountant.
Sediment: Solid matter which settles to the bottom of a liquid.
Sedimentary rocks (sĕd-ĭ-mĕn'tȧ-rĭ): Rocks formed by material deposited in layers. Sandstone and shale are examples.
Seedling: A sprouting seed.
Semicircular canal (sĕm-ĭ-sûr'kū-lȧr): The curved tubular part of the inner ear, filled with liquid. The influence of the semicircular canal on hearing is not known. It is the organ which enables us to keep our balance.
Sensation: The feeling resulting from the stimulation of a sense organ; for example, the effect of sound on the ear.
Septic tank: A tank for making sewage harmless by the action of bacteria.
Serum (sē'rŭm): The watery part of certain animal fluids, such as blood or milk, separated from them by coagulation, or clotting.
Sewage (sū'āj): Wastes from the household.
Sextant: An instrument used in navigation to determine latitude.
Shadow: A dark space caused by an opaque object cutting off light.
Shock: A type of illness characterized by dizziness, shortness of breath, nausea, and sometimes unconsciousness. Often the result of a sudden injury.
Sidereal system (sī-dē'rē-ăl): The starry system.
Sight: Ability to see; vision.
Silica (sĭl'ĭ-kȧ): A mineral having binding qualities; common in sandstones and sands; used in making glass and pottery.
Siphon (sī'fŏn): A device for transferring liquid over an elevation to a lower level.
Skeleton: The bony framework of the body.

Skin: The external covering of the body. It is composed of two layers, the dermis and the epidermis.

Slag: A substance formed by a combination of lime and impurities from ore during smelting. Used in the manufacture of cement.

Sleet: Snow and rain falling together.

Smelting: The process of melting or fusing by which metals are extracted from their ores.

Snow: Tiny crystals of ice, formed by the freezing of water vapor in the air.

Soap: A cleansing agent, usually made by combining an alkali with fat or oil.

Soil: A substance composed of inorganic matter formed by the breaking up of rocks and of organic matter derived from plants and animals. Necessary for the growth of plant life.

Soil exhaustion: A condition of the soil caused by failure to restore to it the nutrients which growing plants have taken from it.

Solar day (sō′lȧr): The length of time which elapses between successive appearances of the sun at its highest point in the heavens.

Solar eclipse: An eclipse of the sun.

Solar system: The sun with the group of planets which revolve around it.

Solar time: Actual time as determined by the sun.

Solid: A substance that will keep its shape without a container to hold it in place.

Soluble (sŏl′ū̇-b′l): Capable of being dissolved, as in a liquid.

Solution (sō̇-lū′shŭn): A complete and perfect mixture of a solid, liquid or gas with a liquid. A mixture of salt and water is a solution.

Solvent (sŏl′vĕnt): A liquid capable of dissolving substances.

Sound: A sensation due to the action of air waves upon the ear.

Sounder: The receiving instrument of a telegraph circuit. It gives out a series of clicks as the charged electric circuit is completed and broken.

Special property: A quality which shows itself in one or more kinds of matter, but not in all kinds.

Species (spē′shēz): A group of animals or plants having one or more common characteristics which distinguish them from other similar groups.

Spectroscope: An instrument for breaking up light to study the colors of which it consists.

Spectrum: A band of seven colors—red, orange, yellow, green, blue, indigo, and violet—formed when white light is broken up, as when passed through a triangular glass prism.

Spinal cord: The cord of nerve tissue connecting with the brain and running lengthwise through the rings of the backbone. The trunk line through which the brain makes nerve connections with all parts of the body.

Spiracles (spĭr′ȧ-k′lz): Minute air holes in the sides of insects, through which they breathe.

Spleen: A ductless gland near the lower wall of the stomach, whose use is not fully understood.

Spontaneous combustion (spŏn-tā′nē̇-ŭs): A fire starting without outside aid, as the bursting into flame of an oily rag due to accumulation of heat from gradual oxidation.

Spores: Bacteria which have developed thick cell walls. These preserve them, inactive but alive, through long periods when conditions are unfavorable for active life.

Sprain: Injury to the muscles, ligaments, or nerves about a joint; caused by the joint being turned too far or in the wrong direction.
Spring: A hole in the ground or a crevice in a rock from which water flows naturally.
Sputum (spū'tŭm): Spit.
Stability (stȧ-bĭl'ĭ-tĭ): Capacity to stay upright or to recover an upright position.
Standard time: The time that has been established by law over a region or country.
Star: A great, blazing sun.
Starch: A most important food substance composed of carbon, oxygen, and hydrogen chemically combined.
Static electricity (stăt'ĭk): Stationary electricity.
Steam: The invisible vapor into which water is changed by boiling.
Steam engine: An engine in which steam is admitted alternately to opposite sides of a piston in a cylinder, its expansion serving to drive the piston back and forth.
Steapsin (stē-ăp'sĭn): A ferment in pancreatic juice which helps digest fat.
Sterilize: To free from bacteria.
Sternum: The breastbone.
Stewing: Cooking in simmering hot water over a slow fire for a number of hours.
Stimulant (stĭm'ū-lănt): A substance capable of acting on the nervous system, causing increased activity of the organs it controls. Tea and coffee are stimulants.
Stimulus (stĭm'ū-lŭs): Anything that arouses the activity of an organ or tissue.
Stipules (stĭp'ūlz): A pair of leaf-like parts situated at the base of some leaf stalks.
Stomach: A pear-shaped pouch in the digestive tract.
Stomata (stō'mȧ-tȧ): Openings in the lower surfaces of leaves for the admission of oxygen.
Storage battery: A collection of storage cells.
Storage cell: A device for storing up electrical energy in the form of chemical energy.
Strain: A muscle injury usually caused by efforts to lift too heavy loads.
Strata (strā'tȧ): Layers; natural rock layers.
Stratus (strā'tŭs): Low, horizontal layers of clouds.
Streamlined body: A body, such as the hull of a ship or the body of an airplane, which is designed to pass through the air or water with only a small amount of resistance.
Structure: The way in which anything is built; the parts of which it is composed.
Sublingual glands (sŭb-lĭn'gwăl): The pair of salivary glands lying under the sides of the tongue.
Submarine: A vessel designed to travel both above and below the surface of the water.
Submaxillary glands (sŭb-măk'sĭ-lå-rĭ): The pair of salivary glands lying just beneath the angles of the lower jaw at each side.
Substance: Matter of any kind.
Suffocation: Inability to breathe.
Sulphates (sŭl'fātz): Mineral substances composed mainly of sulphur and oxygen; needed by the body to make protoplasm, bones, and teeth.
Sulphur: A solid, yellow, non-metallic substance. One of the elements.

Sun: The large, flaming body about which revolve the earth and the other planets; the center of the solar system.
Sunstroke: A dangerous condition caused by exposure to great heat.
Surgery: The treating of disease, deformity and injury by operation.
Suspension bridge: A bridge whose roadway is supported by steel cables strung between lofty supports.
Sweat glands: Glands in the skin that excrete sweat.
Sympathetic system: Two chains of ganglia, or collections of nerves, located on each side of the spinal column and connected with the vital organs of the body, whose actions they regulate.
Systemic circulation: (sĭs-tĕm′ĭk): The circulation of the blood through all parts of the body except the lungs.

T

Talking motion pictures: Motion pictures in which the voices of the actors and all sounds are reproduced to accompany the pictures.
Tannin (tăn′ĭn): An acid substance found in tea.
Tea: A beverage containing a stimulating substance called thein; made from dried tea leaves.
Telegraph: An instrument for sending and receiving messages over a wire by completing and breaking a charged electric circuit.
Telegraph key: An instrument for completing and breaking the charged electric circuit in a telegraph.
Telephone: An instrument for sending and receiving the sound of the human voice over a wire by means of an electric current.
Telephotography (tĕl-ē-fō-tŏg′rȧ-fĭ): The sending of pictures by telegraph or radio.
Telescope: An instrument for seeing distant objects clearly.
Television (tĕl-ē-vĭzh′ŭn): The broadcasting and receiving of images of persons or scenes by radio.
Temperature: Degree of heat.
Tendon: A tough band of connective tissue uniting muscle to muscle or muscle to bone.
Terrarium (tĕ-rā′rĭ-ŭm): A box containing earth, in which both land animals and land plants are kept.
Testa (tĕs′tȧ): The hard outer covering of a seed.
Tetanus (tĕt′ȧ-nŭs): A painful and infectious disease in which some or all of the voluntary muscles become rigid. When confined to the lower jaw, it is called lockjaw.
Thein (thē′ĭn): A stimulating substance found in tea.
Theobromine (thē-ō-brō′mĭn): A stimulating substance in chocolate and cocoa.
Theory: An explanation of some natural occurrence which many experiments and observations seem to indicate to be true.
Therapy (thĕr′ȧ-pĭ): The science which relates to remedies for disease.
Thermal: Pertaining to heat.
Thermometer: An instrument for measuring temperature.
Thermostat (thûr′mō-stăt): An automatic apparatus for regulating temperature indoors.
Thoracic duct (thō-răs′ĭk): The main lymph tube of the body, extending along the front of the spinal column from a region just behind the aorta to the left side of the neck.
Thorax (thō′răks): The part of the body between the neck and the abdomen.
Thunder: The sound which accompanies a flash of lightning.

Thyroid glands (thī'roid): A pair of ductless glands located on each side of the esophagus just below the larynx. Their secretions are necessary to the proper nutrition of the body.

Tides: The regular rise and fall of the ocean every 12 hours and 26 minutes, caused by the attraction of the moon and, to a lesser extent, of the sun. When sun and moon pull together, we have extremely high, or spring, tides, and when they pull at right angles to each other we have low, or neap, tides. A rising tide is called a flood tide, a falling tide an ebb tide.

Time belt: A belt or territory in which the standard time of all places is the same. There are four standard time belts in the United States.

Tissue: A collection of cells joined together, which do a special work.

Tonsils: Two fleshy tissues lying at the back of the mouth.

Tornado (tŏr-nā'dō): An exceedingly violent, whirling wind storm accompanied by thunder, lightning and rain; travels a short distance over a narrow path.

Toxin: A poison produced by the action of bacteria upon organic matter.

Toxin-antitoxin: A mixture which when introduced into the system prevents certain diseases by counteracting the effect of toxins.

Trachea (trā'kē-ȧ): The tube in the body through which animals get air; the windpipe.

Trade winds: Wind currents flowing southwest and northwest from the tropical belts toward the heat equator.

Transformer: A device for increasing or decreasing the voltage, or pressure, of an alternating electric current.

Translucent (trăns-lū'sĕnt): Permitting the passage of light but not vision.

Transmitter: That part of a telegraph or telephone by means of which messages are sent.

Transparent: Permitting the passage of light and vision.

Transpiration (trăn-spĭ-rā'shŭn): Giving off of water vapor by the leaves of plants.

Trap: A bend in a drain pipe to hold water and thus seal the pipe against sewer gas.

Triceps (trī'sĕps): The muscle of the upper arm that extends the forearm.

Triplane: An airplane with three pairs of wings, one above another.

Tropic of Cancer: An imaginary line around the earth parallel to the equator and 23½ degrees north of it.

Tropic of Capricorn: An imaginary line around the earth parallel to the equator and 23½ degrees south of it.

Truss bridge: A bridge built in the form of an open framework of wood or metal.

Trypsin (trĭp'sĭn): A ferment in pancreatic juice which changes albumins to soluble form.

Tsetse fly (tsĕt'sē): An African fly whose bite usually causes sleeping sickness by introducing a parasite into the body.

Tuberculosis (tū-bûr-kū-lō'sĭs): An infectious, wasting disease.

Tungsten (tŭng'stĕn): A grayish-white metal. One of the elements. It is largely used as the filament in bulbs for incandescent lighting.

Tuning: Adjusting a radio to receive waves from a sending station. Adjusting a musical instrument to the proper pitch.

Tuning fork: A forked piece of steel which vibrates at a given rate when struck, producing a certain fixed tone or note. Used in tuning musical instruments.

Turbine: An encased water wheel having a series of curved blades or buckets against which the water strikes, causing rapid motion. A powerful form of steam engine used in steamships.

Tympanic membrane (tĭm-păn′ĭk): The ear drum.

Typhoid fever (tī′foid): A dangerous and infectious disease. Spread by flies, by improper sewage disposal, and by food, water and milk containing typhoid germs.

Typhoon (tī-fōōn′): A hurricane when it occurs over the Pacific ocean.

U

Ultra-violet rays: Light rays having a shorter wave length than violet light; they are invisible to the human eye.

Umbra (ŭm′brȧ): The darkest part of a shadow.

Undershot wheel: A water wheel operated by the force of water flowing against its blades from underneath.

Universe: Everything that exists. This includes the entire solar and sidereal systems.

Urine (ū′rĭn): A fluid waste of the body given off by the kidneys.

V

Vaccination (văk-sĭ-nā′shŭn): Inoculation with a vaccine, usually cowpox, to produce a mild form of smallpox, resulting in subsequent immunity.

Vaccine (văk′sĭn): A substance employed in vaccination to combat smallpox.

Vacuole (văk′ū-ōl): A small area in a protozoan containing food, air or waste.

Vacuum (văk′ū-ŭm): A space from which all air has been exhausted.

Vacuum bottle: A glass bottle within a larger bottle, sealed to it at the neck. The space between is a vacuum. Used to keep hot liquids hot or cold liquids cold.

Vacuum tube: A glass bulb used in radio to change the frequency of sound and radio waves.

Valve: A device for regulating the flow of a gas or liquid, as the valve in a water faucet or the valve by which water is admitted to the tanks of a submarine. Any of the thin, strong flaps of tissue in the heart which allow the blood to flow in only one direction.

Vapor: The gaseous form of a liquid or solid.

Vaporize: To convert into vapor by means of heat.

Variable condenser: A device in a radio receiving set which permits only radio waves of a certain length to pass, thereby allowing but one station at a time to be heard.

Vein: A tube which conveys blood to the heart. A channel through which fluid circulates through a leaf.

Velocity (vē-lŏs′ĭ-tĭ): Rate of speed or movement.

Ventilation: The act of changing or renewing the air supply.

Ventilation systems—

- **Gravity system:** A system of ventilation by which air flows naturally into a building through windows and doors, or through airshafts.
- **Plenum system** (plē′nŭm): A forced system of ventilation by which fresh air is blown into a building by fans, displacing and forcing out the bad air.

Vacuum system: A forced system of ventilation by which bad air is drawn out of a building by fans, fresh air flowing in to take its place.

Ventricle (vĕn′trĭ-k′l): One of the two lower chambers of the heart.

Vermiform appendix (vûr′mĭ-fôrm ă-pĕn′dĭks): A short tube, closed at the outer end, extending from the large intestine near its connection with the small intestine.

Vertebrae (vûr′tē-brē): The bones which make up the spinal column.

Vertebrate: An animal with a backbone, or spinal column.

Vibration: A regular moving to and fro, such as the movement of the pendulum of a clock, or of a quivering musical string.

Villi (vĭl′ī): Hair-like projections in the small intestine for the absorption of food.

Virus (vī′rŭs): The poison by which an infectious disease is spread.

Vitality: Life force.

Vitamins (vī′tȧ-mĭnz): Substances in certain foods; essential for health.

Volatile (vŏl′ȧ-tĭl): Readily changed to vapor.

Volcano: A hill or mountain, usually conical in shape, formed of cinders, ashes, and molten rock thrown out by natural explosions or eruptions from within the earth.

Volt: The standard unit for measuring electromotive force or pressure.

Voltage: Electrical pressure, measured in volts.

Voltmeter: An instrument for measuring volts.

Voluntary muscles: Muscles which perform movements under the guidance of the will, such as movements of the arm and leg.

W

Water: A colorless, odorless, tasteless liquid, a compound of hydrogen and oxygen; essential to life.

Waterspout: A tornado at sea in the form of a whirling column of water.

Water vapor: Water in the form of gas or in small particles floating in the air. Steam from a tea kettle and the unseen moisture which forms dew on cool objects are examples of water vapor.

Watt: A unit for measuring the amount of work an electric current can do.

Weather: The condition of the atmosphere as regards temperature, density, moisture and air motion.

Weather Bureau: A division of the United States Department of Agriculture. It records weather statistics and predicts the weather.

Weather graph: A graph showing the variation of a weather condition, such as atmospheric pressure or rainfull, for a period of time.

Wedge: A piece of wood or metal tapering to a thin edge. One of the basic machines.

Weight: The pull of gravity on a body; the resistance to be overcome by a machine.

Westerlies: Name given to the prevailing winds from the west.

Wheel and axle: A variation of the lever, consisting of a solid cylinder, or axle, to one end of which is attached a wheel or a handle. A slight amount of force applied to the wheel or handle exerts great turning force on the axle. The axle, in turning, winds a rope and lifts a weight. One of the basic machines.

White corpuscles (kôr′pŭs-′lz): Irregularly shaped, colorless cells found in the blood. They destroy disease germs and aid in healing wounds.

White matter: The white nerve tissue, consisting largely of nerve fibers, forming the inside portion of the cerebrum and the cerebellum and the outside covering of the medulla and the spinal cord.
Wind: A horizontal, natural movement of the air.
Wood alcohol: A poisonous alcohol made from wood fiber.
Work: The overcoming of resistance.

X

X-rays: Rays caused by an electric charge passed through a vacuum tube, similar to light rays but of shorter wave length, capable of passing through flesh but not through bones, blood, or other substances containing mineral matter. Used to locate foreign objects lodged in the body, to discover growths on the internal organs, and to determine the extent of injuries to bones either by means of direct vision or through X-ray photographs of the parts affected.

Y

Yeast: A form of fungous plant which causes fermentation. Yeast is used in bread making, as it combines with sugar, thereby forming gas bubbles (fermentation) which lighten the dough.

Z

Zinc: A heavy, bluish-white metal. One of the elements.
Zones: Divisions of the earth according to temperature. There are two frigid, or cold, zones, two temperate zones, and one torrid, or hot zone.
Zoölogy (zô-ŏl'ô-jĭ) **:** The science which treats of animals.

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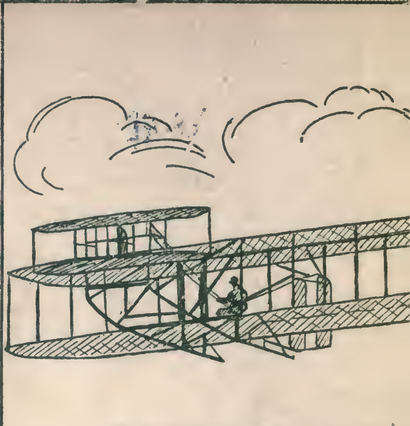
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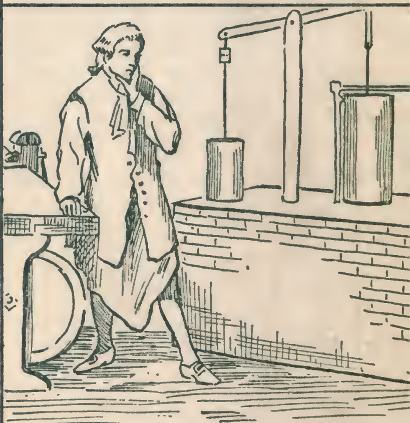
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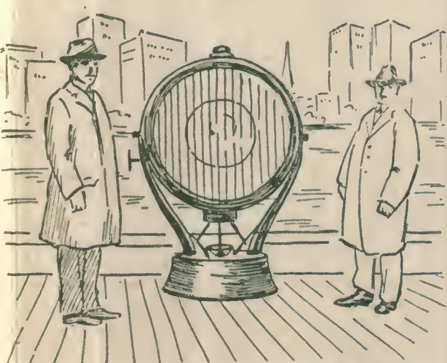

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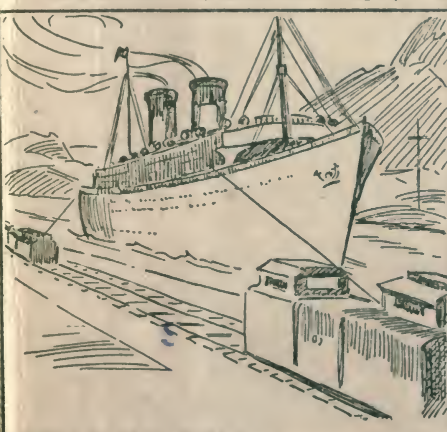

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